The D. H. Hill Library

North Carolina State College
T61
S6
v.5
1897

NORTH CAROLINA STATE UNIVERSITY LIBRARIES
S01846535 W

41583

T61
S6
v.5
1897

Society for the promotion of engineering education
Proceedings

DATE	ISSUED TO
19Jun'61N	[illegible]

This BOOK may be kept out TWO WEEKS ONLY, and is subject to a fine of FIVE CENTS a day thereafter. It is due on the day indicated below:

41583

19Jun'61N

Digitized by the Internet Archive
in 2010 with funding from
NCSU Libraries

http://www.archive.org/details/engineeringeduca05soci

De Volson Wood

Society

FOR THE

Promotion of Engineering Education.

PROCEEDINGS

OF THE

FIFTH ANNUAL MEETING,

HELD IN

TORONTO, ONTARIO, AUGUST 16, 17, 18, 1897.

Volume V.

EDITED BY

JOHN B. JOHNSON, C. FRANK ALLEN, ALBERT KINGSBURY,
Committee.

PUBLISHED BY THE SOCIETY.
1898.

PRESS OF
THE NEW ERA PRINTING COMPANY,
LANCASTER, PA.

TABLE OF CONTENTS.—Vol. V.

Page.

Portrait of Professor De Volson Wood, . . *Frontispiece*
List of Officers, ... v
List of Committees, ... v
List of Council, ... vi
List of Members, ... vii
Distribution of Members, ... xix
List of Past Officers, ... xx
List of Members of Previous Councils, ... xx
Constitution, ... xxi
Rules Governing the Council, ... xxii
Proceedings of the Meeting at Toronto, . . . 1
    Report of the Committee on Entrance Requirements, 5
    Report of the Committee on Uniformity of Symbols, 6
    Report of the Auditing Committee, 6
    Report of the Nominating Committee, 6
    Report of the Secretary, 7
    Report of the Treasurer, 9
Address by the President.—*Eddy*, ... 11
Engineering Laboratory Courses.—*R. C. Carpenter*, . 26
    Discussion—*Johnson, Eddy*, ... 38
A Course of Study in Electrical Engineering.—*Owens*, 40
At What Point should Students Engage in Specific Research, and How Much Aid should be Given by the Professor.—*Marx*, ... 47
    Discussion—*Johnson, Eddy*, ... 51
Uniformity of Symbols.—Report of Special Committee, 53
Electrical Engineering Symbols.—*D. C. Jackson*, . 55
Mechanical Engineering Symbols.—*Kent*, . . . 67
Symbols for Statics, Dynamics, Strength and Elasticity of Materials, Hydraulics, and Thermodynamics.—*Galbraith*, ... 77
Symbols for Strength of Materials, Framed Structures, Masonry, and Surveying.—*Johnson*, . . . 84
    Discussion on Symbols—*Mendenhall, Greenhill, R. S. Woodward, Unwin, Macfarlane, Caldwell*, . . 89

41563

METHODS OF TEACHING—*CREIGHTON*, ... 104

DISCUSSION—*Allen, Gray, Eddy*, ... 113

ELECTIVE STUDIES IN THE REGULAR ENGINEERING COURSES.—*Munroe*, ... 117

DISCUSSION—*Eddy, Allen, Sackett, Johnson, Kidwell, R. C. Carpenter, Ordway, Greenhill*, ... 126

THE CALCULUS FOR ENGINEERING STUDENTS.—*McNair*, . 139

DISCUSSION—*Johnson, Eddy, Kidwell, Ordway, Tyler, Sackett, Bull, Gray, Allen, Ostrander*, ... 149

THE INFLUENCE OF SCIENTIFIC RESEARCH UPON THE DEVELOPMENT OF CHEMICAL TECHNOLOGY.—*BUNTE*, . . 161

CHEMICAL ENGINEERING.—*ORDWAY*, ... 187

DISCUSSION ON THE ABOVE TWO PAPERS—*Johnson, Ordway, Eddy, Bull, Kidwell, Tyler, Wernicke, McMahon, Magruder*, ... 193

THE TEACHING OF MACHINE DESIGN.—*FLATHER*, . . 200

DISCUSSION—*Ordway, Flather, Bull, Magruder, Kidwell*, 207

THE EFFICIENCY OF TECHNICAL AS COMPARED WITH LITERARY TRAINING.—*MENDENHALL*, ... 211

DISCUSSION—*Murkland, Eddy, Allen, Kidwell, Mees, Lambert, Galbraith, Constant, Waldo, Johnson, Ordway, Tyler*, 224

A COURSE IN FRENCH AND GERMAN FOR ENGINEERS.—*VANDAELL*, ... 247

DISCUSSION—*Wernicke, Flather, Allen*, ... 258

THE EXTENT TO WHICH METALLURGY SHOULD BE TAUGHT IN ENGINEERING COURSES.—*COOLEY*, ... 262

DISCUSSION—*Ordway, Flather*, ... 263

MANUAL TRAINING FOR ARTISANS.—*C. M. WOODWARD*, . 264

THE MANUAL TRAINING HIGH SCHOOL.—*MATHER*, . . 272

DISCUSSION ON THE ABOVE TWO PAPERS—*Johnson, Tyler, Flather, Allen, Ordway, Eddy, Waldo, R. C. Carpenter*, 284

THE AGRICULTURAL COLLEGE IN ITS RELATION TO ENGINEERING EDUCATION.—*MURKLAND*, ... 295

DISCUSSION—*Aldrich, Mees, Bull*, ... 304

GRADUATION THESES: THEIR PREPARATION, FORM, AND PRESERVATION.—*BAKER*, ... 312

DISCUSSION—*Kidwell, Caldwell, Mees, R. C. Carpenter, Johnson, Bull, Flather, Eddy, Wernicke*, . . 320

MEMORIAL NOTICE OF PROFESSOR DE VOLSON WOOD, . . 325

INDEX 331

TABLE OF CONTENTS.—VOL. I.

PAGE.

CONSTITUTION OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, ... 7

COUNCIL OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, ... 3

PROCEEDINGS OF OPENING SESSION, ENGINEERING CONGRESS, 1

PROGRAM OF DIVISION E ON ENGINEERING EDUCATION, 4

PROCEEDINGS OF DIVISION E, ... 1

THE IDEAL ENGINEERING EDUCATION.—*BURR*, . . 17

REQUIREMENTS IN MATHEMATICS FOR ENGINEERING EDUCATION.—*TALBOT*, ... 50

PRESENT FAVORABLE AND UNFAVORABLE TENDENCIES IN ENGINEERING EDUCATION.—*RICKETTS*, . . . 63

COMPARISON BETWEEN AMERICAN AND EUROPEAN METHODS IN ENGINEERING EDUCATION.—*SWAIN*, . . . 75

DISCUSSION—*Goodman, Bull, Eddy, Johnson, Robinson, Christy, Allen, Wood, Burr*, ... 102

THE GROWTH OF AMERICAN MINING SCHOOLS AND THEIR RELATION TO THE MINING INDUSTRY.—*CHRISTY*, 118

THE EQUIPMENT OF ENGINEERING SCHOOLS.—*THURSTON*, 152

DISCUSSION—*Johnson, Eddy, Jacobus, Spangler, Carpenter, Ritter, S. W. Robinson, Tracy*, . . . 167

THE HYDRAULIC LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.—*D. PORTER*, . . 177

DISCUSSION—*Merritt, Porter, Goodman, S. W. Robinson, Talbot*, ... 181

THE TEACHING OF GRAPHICAL METHODS IN ENGINEERING COLLEGES AND SCHOOLS.—*HELE-SHAW*, . . 184

DISCUSSION—*Eddy, Merriman, Johnson, Jacobus, R. C. Carpenter, Goodman, Landreth, Spangler, Kinealy, S. W. Robinson, Hibbard, Ritter, Humphreys, R. S. Woodward*, ... 204

ON ORIGINAL RESEARCH BY STUDENTS IN UNDERGRADUATE COURSES IN ENGINEERING, ESPECIALLY CIVIL ENGINEERING.—*MARX*, ... 207

TABLE OF CONTENTS.—VOL. I.

ORIGINAL RESEARCH BY STUDENTS.—*R. C. CARPENTER*, 217

DISCUSSION—*Jacobus*, *Spangler*, and *Carpenter*, . 226

FIELD PRACTICE AND FIELD EQUIPMENT.—*JAMISON*, . 232

DISCUSSION — INCLUDING A DESCRIPTION OF THE FIELD-WORK IN SURVEYING AT COLUMBIA COLLEGE.—*Munroe*, *Burton*, *Merriman*, ... 243

TRAINING OF STUDENTS IN TECHNICAL LITERARY WORK.—*MERRIMAN*, ... 259

METHODS OF STUDYING CURRENT TECHNICAL LITERATURE.—*JOHNSON*, ... 265

DISCUSSION—*Landreth*, *Wood*, *Swain*, *Lanza*, *Talbot*, *Eddy*, ... 268

DRAWING FOR ENGINEERING STUDENTS.—*DENISON*, . 270

DISCUSSION—*Baldwin*, *Spangler*, *Dunlap*, . . 282

VACATION WORK.—*BURTON*, ... 287

DISCUSSION—*Johnson*, *Humphreys*, *Merriman*, *Rickets*, *Talbot*, *Burton*, ... 299

GRADUATING THESES.—*LANZA*, ... 307

DISCUSSION—*Johnson*, *Aldrich*, *Ricketts*, *Lanza*, *Wood*, 322

PROCEEDINGS OF THE CLOSING SESSION OF THE CONGRESS, 329

INDEX, ... 4

TABLE OF CONTENTS.—Vol. II.

Page

OBJECTS OF THE SOCIETY, ...

LIST OF OFFICERS, ...

CONSTITUTION, ...

RULES OF THE COUNCIL, ...

PROCEEDINGS OF THE BROOKLYN MEETING, ... 1

LIST OF MEMBERS, ... 8

ADDRESS OF THE PRESIDENT.—*WOOD*, ... 21

COMMON REQUIREMENTS FOR ADMISSION TO ENGINEERING COURSES.—*MARVIN*, ... 39

DISCUSSION—*Baker*, *Tyler*, *Kingsbury*, ... 56

GRADUATE AND POSTGRADUATE ENGINEERING DEGREES.—Three Papers, ...

First Paper.—*RICKETTS*, ... 59

Second Paper.—*SWAIN*, ... 62

Third Paper.—*THURSTON*, ... 75

TEACHERS AND TEXT-BOOKS IN MATHEMATICS IN ENGINEERING SCHOOLS.—*MERRIMAN*, ... 95

DISCUSSION—*Carson*, ... 103

THE TEACHING OF ENGINEERING SPECIFICATIONS AND THE LAW OF CONTRACTS TO ENGINEERING STUDENTS.—*JOHNSON*, 109

MECHANICAL DRAWING IN TECHNICAL SCHOOLS.—*FLATHER*, 113

SOME GERMAN TECHNICAL SCHOOLS.—*BULL*, . . . 132

THE ORGANIZATION AND CONDUCT OF ENGINEERING LABORATORIES.—*LANZA*, ... 149

EARLY INSTRUCTION—PHYSICS AND MECHANICS.—*C. M. WOODWARD*, ... 162

MINIMUM LABORATORY WORK AND EQIPMENT IN A CIVIL ENGINEERING COURSE.—*D. PORTER*, ... 169

A FEW MISTAKES IN THE CONDUCT OF COLLEGE FIELD-PRACTICE.—*STOUT*, ... 180

TABLE OF CONTENTS.—VOL. II.

Courses in Structural Engineering.—*Marburg*, . . . 186

Amount and Kind of Shop Work Required in a Mechanical Engineering Course.—*Marx*, ... 206

Mechanical Laboratory Work at Ames, Iowa.—*Bissell*, ... 217

Electrical Engineering Laboratories.—*Jackson*, . 221

Teaching Machine Design.—*Barr*, ... 236

The Education of Civil Engineers for Railroad Service.—*Allen*, ... 253

Engineering Education and the State University.—*Aldrich*, ... 268

TABLE OF CONTENTS.—Vol. III.

Page.

List of Officers, ... vii

List of Members, ... viii

Distribution of Members, ... xviii

Constitution, ... xix

Rules of the Council, ... xx

Proceedings of Meeting at Springfield, Mass., . 1

Report of the Secretary, 9

Report of the Treasurer, 10

Address by the President.—*Swain,* 13

Entrance Requirements for Engineering Colleges.—Report of Committee, ... 25

Discussion—*Merriman, Fava, Johnson, Mees, Bull, Galbraith, Raymond,* 46

The Scope of an Engineering College.—*Raymond.* . 50

Discussion—*Allen, Flather, Fava, D. Porter, Marvin, Kent, Raymond,* 62

The Present Requirements of American Engineering Colleges in Non-Professional Studies.—*Reber,* . 74

The Elective System as Adopted in the Michigan Mining School.—*M. E. Wadsworth* 92

Discussion—*Merriman, Galbraith, Ordway, Hofman,* 98

Graphic Methods in Engineering Education.—*Hoskins,* 101

Discussion—*Johnson, R. S. Woodward, Merriman, Fava,* 108

Specifications for Text-Books.—*Baker,* . . . 111

Discussion—*Swain, Marvin, Jacoby, Fava, Merriman, Allen, Baker,* 122

The True Place of Drawing and Shopwork in Engineering Colleges.—*Benjamin,* 126

Discussion—*Spangler, Ordway, Higgins,* . . 132

Graduation, Thesis, and Degrees.—*Bull,* 137

Discussion—*Johnson, Lanza, Gray, Williams, Doolittle, Marvin, Raymond, Merriman, Allen, Kent, Bull,* . 147

Modified Requirements for Graduation of Students who have taken Full Literary Courses.—*Hollis,* 164

Discussion—*Bull, Kingsbury,* 170

TABLE OF CONTENTS.—VOL. III.

The Comparative Value of Graduate Study in Engineering Courses.—*Burr*, ... 171

Discussion—*Kent*, ... 179

The Economic Element in Technical Education.—*Randolph*. 181

Discussion—*Kent*, *Flather*, *Galbraith*, *Kingsbury*, . 186

Unsymmetrical Development of Engineering Courses.—*Hutton*, ... 189

The Civil Engineer of the Twentieth Century.—*Corthell*, ... 194

Discussion, *Merriman*, *Johnson*, *Lanza*, *Raymond*, *Kent*, 210

A Course of Study in Physics.—*Mees*, ... 213

Discussion—*Galbraith*, *Merriman*, *Kingsbury*, *Mees*, 226

A Course of Study in Mechanics.—*R. S. Woodward*, . 229

Discussion—*Galbraith*, *Mendenhall*, *Merriman*, *Kent*, *R. S. Woodward*, ... 241

A Course in Astronomy for Engineering Students.—*Comstock*, ... 246

A Specialized Course in Geodetic Engineering.—*Merriman*, ... 256

Discussion on above two papers—*Marvin*, *Allen*, . 258

A Course in Biological Sciences for Engineering Students.—*Hall*, ... 261

Discussion—*C. C. Brown*, *Kent*, ... 266

A General Course in Civil Engineering.—*Crandall*, 268

Discussion—*Swain*, ... 274

A Course in Sanitary Engineering.—*C. C. Brown*, . 275

Discussion—*Galbraith*, *Marvin*, *D. Porter*, *C. C. Brown*, 280

A Course in Mechanical Engineering.—*Spangler*, . 284

Teaching Industrial Applications of Electricity.—*Shepardson*, ... 309

A Course in Mining Engineering.—*Chauvenet*, . . 313

Discussion—*Hofman*, ... 335

The Equipment of Mining and Metallurgical Laboratories.—*Hofman*, ... 337

Discussion—*Swain*, *Johnson*, ... 383

A Course of Instruction in Engineering Materials.—*Johnson*, ... 384

Discussion—*Kent*, *Galbraith*, *Merriman*, *Johnson*, . 393

Index, ... 396

TABLE OF CONTENTS.—Vol. IV.

Page.

List of Officers, ... vii
List of Council, ... vii
List of Members, ... ix
Distribution of Members, ... xx
Constitution, ... xxi
Rules of the Council, ... xxii
Proceedings of Meeting at Buffalo, . . . 1

Report of the Secretary, 11
Report of the Treasurer, 13
Report of the Auditing Committee, 15

Address by the President.—*Merriman*, . . . 16
A Quarter Century on Progress in Engineering Education.—*Fletcher*, ... 31
Discussion—*Randolph*, ... 48
Some Notes upon Civil Engineering Education with Special Application to Japan.—*Waddell*, . 51
Discussion—*Mendenhall, Gray*, ... 57
Agreement on Definition of Engineering Terms.—*Gray*, 61
Discussion—*Galbraith, Ordway, Fuertes, Gray*, . 66
The Elective System in Engineering Colleges.—*M. E. Wadsworth*, ... 70
Discussion—*Wood, Galbraith, Jacoby, Bull, Goss, Bissell, Kingsbury, Hatt, Magruder, Wadsworth*, . . 85
Entrance Requirements for Engineering Colleges.—Report of the Special Committee, ... 101
The Conservation of Government Energy through Education and Research.—*Hall*, ... 174
The Hale Engineering Experiment Station Bill.—*Aldrich*, ... 187
Discussion on the above two papers—*Wood, Fuertes, Mendenhall, Gray, Goss, Randolph, Hamlin, Hatt, Ostrander, Magruder, Hall*, ... 191

TABLE OF CONTENTS.—VOL. IV.

THE SEMINAR METHOD OF INSTRUCTION AS APPLIED TO ENGINEERING SUBJECTS.—*SPALDING*, ... 216

DISCUSSION—*Wood, Turneaure, Fletcher, Bull, Allen, Hatt, Randolph, Constant, Goss, Shepardson*, . . . 221

QUANTITY *vs.* QUALITY IN SMALLER COLLEGES.—*KINGSBURY*, 230

HOW TO DIVIDE SUBJECTS FOR ORIGINAL INVESTIGATION AMONG DIFFERENT COLLEGES.—*BENJAMIN*, . . . 237

DISCUSSION—*Shepardson, Bissell, Bull*, . . . 240

ON THE DESIRABILITY OF INSTRUCTION OF UNDERGRADUATES IN THE ETHICS OF THE ENGINEERING PROFESSION.—*C. C. BROWN*, ... 242

DISCUSSION—*M. E. Wadsworth, Randolph, Fuertes, Allen*, 245

THE STUDY OF MODERN LANGUAGES IN ENGINEERING COURSES.—*DROWN*, ... 250

DISCUSSION—*Wood, Bull, Fuertes, Tyler, Mees, M. E. Wadsworth*, ... 254

THE METHOD OF TEACHING PERSPECTIVE TO ENGINEERING STUDENTS.—*JACOBY*, ... 261

DISCUSSION—*Kingsbury, Hatt, Jacoby*, . . . 269

MODELLING AS AN AID TO INSTRUCTION IN MACHINE DESIGN. —*BISSELL*, ... 273

DISCUSSION—*Flather, Goss, Bissell*, . . . 277

A COURSE IN NAVAL ARCHITECTURE.—*PEABODY*, . . 278

A COURSE IN MUNICIPAL AND SANITARY ENGINEERING. —*TALBOT*, ... 292

DISCUSSION—*Merriman, Allen, Hatt, Fletcher*, . 296

BIOLOGY FOR CIVIL ENGINEERS.—*WHIPPLE*, . . . 299

DISCUSSION—*Fletcher, Bissell*, ... 315

AN EXPERIMENT IN THE CONDUCT OF FIELD PRACTICE. —*MARVIN*, ... 317

DISCUSSION—*Fuertes, M. E. Wadsworth, Allen*, . 324

CREDIT FOR SHOP EXPERIENCE IN ENTRANCE EXAMINATIONS. —*MAGRUDER*, ... 331

DISCUSSION—*Bull*, ... 338

IS NOT TOO MUCH TIME GIVEN TO MERELY MANUAL WORK IN THE SHOPS?—*SCHUERMAN*, ... 340

DISCUSSION—*M. E. Wadsworth, Randolph, Galbraith, Gray, Bull, Towle, Flather*, ... 343

INDEX. 357

OFFICERS

OF THE

Society for the Promotion of Engineering Education

1897-8.

PRESIDENT.

JOHN B. JOHNSON, Washington University.

VICE-PRESIDENTS.

THOMAS C. MENDENHALL, Worcester Polytechnic Institute.
HARRY W. TYLER, Massachusetts Institute of Technology.

TREASURER.

JOHN J. FLATHER, Purdue University, Lafayette, Ind.

SECRETARY.

ALBERT KINGSBURY, New Hampshire College, Durham, N. H.

COMMITTEES.

On Entrance Requirements for Engineering Colleges.

FRANK O. MARVIN, JOHN J. FLATHER, JOSEPH P. JACKSON, MANSFIELD MERRIMAN, HARRY W. TYLER.

On Uniformity of Symbols for Engineering Text-Books.

THOMAS C. MENDENHALL, STORM BULL, HERMANN S. HERING, GEORGE F. SWAIN, ROBERT S. WOODWARD.

COUNCIL.

Terms of Office Expire in 1898.

C. FRANK ALLEN, Massachusetts Institute of Technology.
CARL L. MEES, Rose Polytechnic Institute.
MANSFIELD MERRIMAN, Lehigh University.
JOHN M. ORDWAY, Tulane University.
WILLIAM G. RAYMOND, Rensselaer Polytechnic Institute.
CADY STALEY, Case School of Applied Science.
ROBERT S. WOODWARD, Columbia University.

Terms of Office Expire in 1899.

ARTHUR BEARDSLEY, Swarthmore College.
ROBERT FLETCHER, Dartmouth College.
JOHN GALBRAITH, School of Practical Science, Toronto.
WILLIAM KENT, Engineering News.
THOMAS C. MENDENHALL, Worcester Polytechnic Institute.
WILLIAM H. SCHUERMAN, Vanderbilt University.
M. EDWARD WADSWORTH, Michigan College of Mines.

Terms of Office Expire in 1900.

STORM BULL, Universty of Wisconsin.
LOUIS G. CARPENTER, Colorado State Agricultural College.
ALBERT KINGSBURY, New Hampshire College of Agriculture and the Mechanic Arts.
FRANK O. MARVIN, University of Kansas.
ROBERT B. OWENS, University of Nebraska.
ROBERT L. SACKETT, Earlham College.
ROBERT H. THURSTON, Cornell University.

LIST OF MEMBERS.

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
ADAMS, COMFORT A., JR. ,… Cambridge, Mass.	Assistant Professor of Electrical Engineering, Harvard University……	1894
ALDRICH, WILLIAM S.,…… Morgantown, W. Va.	Professor of Mechanical Engineering, University of West Virginia,…………	1893
ALLEN, C. FRANK,………… Boston, Mass.	Professor of Railroad Engineering, Massachusetts Institute of Technology….	1893
AMES, WILLIAM L.,………… Worcester, Mass.	Professor of Drawing and Machine Design, Worcester Polytechnic Institute, …….	1895
ANDERSON, F. PAUL,………. Lexington, Ky.	Professor of Mechanical Engineering, Kentucky Agricultural and Mechanical College………………………………	1894
ANTHONY, GARDNER C.,….. Tufts College, Mass.	Professor of Technical Drawing, Tufts College …………………………	1896
APPLEBY, WILLIAM R.,…… Minneapolis, Minn.	Professor of Metallurgy, University of Minnesota………………	1896
ARNOLD, BION J.,…………… Chicago, Ill.	Consulting Electrical Engineer……………	1896
AYER, ARTHUR W.,………… Burlington, Vt.	Professor of Mechanical Engineering, University of Vermont…………………	1894
BAKER, IRA O.,……………… Champaign, Ill.	Professor of Civil Engineering, University of Illinois……………………	1893
BALDWIN, WARD,…………… Cincinnati, Ohio.	Professor of Civil Engineering, University of Cincinnati………………	1893
BARBOUR, VOLNEY G., ……. Burlington, Vt.	Professor of Mechanics and Bridge Engineering, Dean of Engineering Department, University of Vermont…………	1894
BARNEY, SAMUEL E., JR.,… New Haven, Con.	Assistant Professor of Civil Engineering, Yale University……………………… ..	1894
BEARDSLEY, ARTHUR, …….. Swarthmore, Pa.	Professor of Engineering, Swarthmore College ……………………	1893
BENJAMIN, CHARLES H. ,…. Cleveland, Ohio.	Professor of Mechanical Engineering, Case School of Applied Science………	1893
BEYER, T. RAYMOND,……… State College, Pa.	Assistant Professor of Civil Engineering, Pennsylvania State College……………	1895

Name and Address.	Title.	Date of Membership.
Bissell, George W., Ames, Iowa.	Professor of Mechanical Engineering, Iowa Agricultural College	1894
Bovey, Henry T., Montreal, Que.	Professor of Civil Engineering and Applied Mechanics, McGill University	1893
Bradford, Joseph N., Columbus, Ohio.	Associate Professor of Drawing, Ohio State University	1896
Bray, Charles D., Tufts College, Mass.	Professor of Civil and Mechanical Engineering, Tufts College,	1894
Breckenridge, Lester P., Champaign, Ill.	Professor of Mechanical Engineering, University of Illinois	1893
Brill, George M. Chicago, Ill.	Supervising Engineer, Swift & Co.	1894
Brown, Charles C., Bloomington, Ill.	Consulting Engineer,	1894
Brown, Charles S., Nashville, Tenn.	Professor of Mechanical Engineering, Vanderbilt University	1895
Bull, Storm, Madison, Wis.	Professor of Steam Engineering, University of Wisconsin	1893
Bunte, Hans, Karlsruhe, Germany.	Aulic Counselor, Professor in the Polytechnic, Director of the Institute of Chemistry and Technology and of the Grand-Ducal Experiment Station	1893
Burgess, Charles, Madison, Wis.	Instructor in Electrical Engineering, University of Wisconsin	1895
Burnham, Alton C., Urbana, Ill.	Instructor in Mathematics, University of Illinois	1896
Burr, William H., New York, N. Y.	Professor of Civil Engineering, Columbia University	1893
Burton, Alfred E., Boston, Mass.	Professor of Topographical Engineering, Massachusetts Institute of Technology	1893
Caldwell, Francis C., Columbus, Ohio.	Associate Professor of Electrical Engineering, Ohio State University	1897
Carpenter, Louis G., Fort Collins, Colo.	Professor of Civil and Irrigation Engineering, Colorado State Agricultural College	1895
Garpenter, Rolla C., Ithaca, N. Y.	Professor of Experimental Engineering, Cornell University	1893
Carson, William W., Knoxville, Tenn.	Professor of Civil Engineering, University of Tennessee	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
CHAUVENET, REGIS, Golden, Colo.	President, School of Mines	1896
CHRISTIANSEN, PETER, Minneapolis, Minn.	Instructor in Metallurgy, University of Minnessota	1896
CHRISTY, SAMUEL B., Berkeley, Cal.	Professor of Mining and Metallurgy, University of California	1893
CLARK, GEORGE S., Highland Home, Ala.	Professor of Engineering and Physics, Highland Home College	1895
COLBURN, LUKE C., Laramie, Wyo.	Professor of Mechanical Engineering and Mathematics, University of Wyoming.	1894
CONSTANT, FRANK H., Minneapolis, Minn.	Assistant Professor of Civil Engineering, University of Minnesota	1896
COOLEY, MORTIMER E., Ann Arbor, Mich.	Professor of Mechanical Engineering, University of Michigan	1893
CORTHELL, ELMER L., 71 Broadway, New York.	Civil Engineer	1895
CORY, HARRY T., Columbia, Mo.	Professor of Civil Engineering, Missouri State University	1895
CRANDALL, CHARLES L., Ithaca, N. Y.	Professor of Civil Engineering, Cornell University	1893
CREIGHTON, W. H. P., New Orleans, La.	Professor of Mechanical Engineering, Tulane University,	1893
CRENSHAW, BOLLING H., Auburn, Ala.	Assistant in Mechanical Engineering, Alabama Polytechnic Institute	1894
CROSS, CHARLES R., Boston, Mass.	Professor of Physics, Massachusetts Institute of Technology.	1895
CUMINGS, HOMER P., Schenectady, N. Y.	Instructor in Civil Engineering, Union College	1894
DANIELS, Frank T., Tufts College, Mass.	Instructor in Civil Engineering, Tufts College	1896
DE BRAY, M., Paris, France.	Professor, École des Ponts et Chaussées	1893
DENISON, CHARLES S., Ann Arbor, Mich.	Professor of Descriptive Geometry, Stereotomy and Drawing, University of Michigan	1893
DENTON, JAMES E., Hoboken, N. J.	Professor of Experimental Mechanics and Superintendent of Tests, Stevens Institute of Technology	1893
DENTON, FRED W., Minneapolis, Minn.	Professor of Mining Engineering, University of Minnesota	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
DROWN, THOMAS M., South Bethlehem, Pa.	President, Lehigh University	1895
DU BOIS, A. JAY, New Haven, Conn.	Professor of Civil Engineering, Yale University	1894
DUDLEY, CHARLES B., Altoona, Pa.	Chemist, Pennsylvania Railroad Company	1894
EDDY, HENRY T., Minneapolis, Minn.	Professor of Mechanics, University of Minnesota	1893
EMORY, FREDERICK L., Morgantown, W. Va.	Professor of Mechanics and Applied Mechanics, University of West Virginia.	1894
ENGLER, EDMUND A., St. Louis, Mo.	Professor of Mathematics and Dean of the Engineering School, Washington University	1897
FARWELL, ELMER S., Washington, D. C.,	Associate Professor of Mechanical Engineering, Columbian University	1895
FLATHER, JOHN J., Lafayette, Ind.	Professor of Mechanical Engineering, Purdue University	1893
FLETCHER, ROBERT, Hanover, N. H.	Professor of Civil Engineering, Director of Thayer School, Dartmouth College	1894
FOSS, FRED E., State College, Pa.	Professor of Civil Engineering, Pennsylvania State College	1893
FRANKFORTER, GEORGE B., Minneapolis, Minn.	Professor of Chemistry, University of Minnesota	1897
FUERTES, ESTEVAN A., Ithaca, N. Y.	Director of College of Civil Engineering, Cornell University	1894
FULLAN, M. THOMAS J., Auburn, Ala.	Assistant in Mechanical Engineering, Alabama Polytechnic Institute	1897
FULTON, HENRY, Boulder, Colo.	Professor of Civil Engineering, University of Colorado	1894
GALBRAITH, JOHN, Toronto, Ont.	Professor of Engineering, School of Practical Science	1893
GEER, HERBERT G., Baltimore, Md.	Associate in Mechanical Engineering, Johns Hopkins University	1894
GIESECKE, F. E., College Station, Tex.	Professor of Drawing, Texas Agricultural and Mechanical College,	1893
GILL, JAMES H., Minneapolis, Minn.	Instructor in Mechanical Engineering, The University of Minnesota	1896
GOLDSBOROUGH, WINDER E., Lafayette, Ind.	Professor of Electrical Engineering, Purdue University	1897

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
GOODMAN, JOHN, Leeds, England.	Professor of Engineering, Yorkshire College, Victoria University.	1893
GOSS, WILLIAM F. M., Lafayette, Ind.	Professor of Experimental Engineering, Purdue University	1893
GRAY, THOMAS, Terre Haute, Ind.	Professor of Dynamic Engineering, Rose Polytechnic Institute	1895
GROVER, NATHAN C., Orono, Me.	Assistant Professor of Civil Engineering, University of Maine	1894
HALL, CHRISTOPHER W., Minneapolis, Minn.	Professor of Geology and Mineralogy, University of Minnesota	1894
HAMLIN, GEORGE H., Orono, Me.	Professor of Civil Engineering, University of Maine	1895
HAMPSON, WILLIAM B., Lincoln, Neb.	Instructor in Mechanical Engineering, University of Nebraska	1896
HARRIS, ABRAM W., Orono, Me.	President, University of Maine	1897
HARRIS, ELMO G., Rolla, Mo.	Professor of Engineering, Missouri School of Mines	1894
HATT, WILLIAM K., Lafayette, Ind.	Associate Professor of Applied Mechanics, Purdue University	1895
HAYNES, ARTHUR E., Minneapolis, Minn.	Professor of Mathematics, University of Minnesota	1895
HAZEN, JOHN V., Hanover, N. H.	Professor of Civil Engineering, Dartmouth College	1896
HELE-SHAW, H. L., Liverpool, England.	Professor of Engineering, University College	1893
HERING, HERMANN S., Baltimore, Md.	Associate in Electrical Engineering, Johns Hopkins University	1894
HIBBARD, H. WADE, Minneapolis, Minn.	Assistant Professor of Mechanical Engineering, University of Minnesota	1896
HILL, JOHN E., Providence, R. I.	Associate Professor of Civil Engineering, Brown University	1894
HOAG, WILLIAM R., Minneapolis, Minn.	Professor of Civil Engineering, University of Minnesota	1893
HOFMAN, HEINRICH O., Boston, Mass.	Associate Professor of Mining and Metallurgy, Massachusetts Institute of Technology.	1894
HOLLIS, IRA N., Cambridge, Mass.	Professor of Engineering, Harvard University	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
HOOD, OZNI P., Manhattan, Kans.	Professor of Mechanics and Engineering, Kansas State Agricultural College	1893
HOSKINS, LEANDER M., Stanford University, Cal.	Professor of Applied Mechanics, Leland Stanford Junior University	1893
HOWE, MALVERD A., Terre Haute, Ind.	Professor of Civil Engineering, Rose Polytechnic Institute	1894
HUME, ALFRED, University, Miss.	Professor of Mathematics, University of Mississippi	1894
HUMPHREYS, DAVID C., Lexington, Va.	Professor of Civil Engineering, Washington and Lee University	1893
HUTTON, FREDERICK R., New York, N. Y.	Professor of Mechanical Engineering, Columbia University	1894
JACKSON, DUGALD C., Madison, Wis.	Professor of Electrical Engineering, University of Wisconsin	1893
JACKSON, JOHN P., State College, Pa.	Professor of Electrical Engineering, Pennsylvania State College	1894
JACOBUS, D. S., Hoboken, N. J.	Assistant Professor of Experimental Mechanics, Stevens Institute of Technology	1893
JACOBY, HENRY S., Ithaca, N. Y.	Associate Professor of Bridge Engineering and Graphics, Cornell University	1894
JOHNSON, JOHN B., St. Louis, Mo.	Professor of Civil Engineering, Washington University	1893
JONES, CLEMENT R., Morgantown, W. Va.	Assistant in Mechanical Engineering, University of West Virginia	1895
JONES, FORREST R., Madison, Wis.	Professor of Machine Design, University of Wisconsin	1893
KEENE, EDWARD S., Fargo, N. Dak.	Professor of Mechanics, North Dakota Agricultural College.	1894
KENT, WILLIAM, Passaic, N. J.	Consulting Engineer, Associate Editor of Engineering News, New York City	1894
KIDWELL, EDGAR, Houghton, Mich.	Professor of Mechanical and Electrical Engineering, Michigan Mining School.	1896
KIMBALL, RODNEY G., Brooklyn, N. Y.	Professor of Applied Mathematics, The Polytechnic Institute of Brooklyn.	1894
KINEALY, J. H., St. Louis, Mo.	Professor of Mechanical Engineering, Washington University	1893
KINGSBURY, ALBERT, Durham, N. H.	Professor of Mechanical Engineering, New Hampshire College of Agriculture and the Mechanic Arts	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
KIRCHNER, WILLIAM H., ... Minneapolis, Minn.	Assistant Professor of Drawing, University of Minnesota	1896
KYSER, HENRY H., Auburn, Ala.	Instructor in Physics, Director of Physical Laboratory, Alabama Polytechnic Institute	1897
LAMBERT, PRESTON A., South Bethlehem, Pa.	Assistant Professor of Mathematics, Lehigh University	1897
LANDRETH, OLIN H., Schenectady, N. Y.	Professor of Civil Engineering, Union College	1893
LANPHEAR, BURTON S., Orono, Me.	Instructor in Electrical Engineering, University of Maine	1897
LANZA, GAETANO, Boston, Mass.	Professor of Applied Mechanics, in charge of the Department of Mechanical Engineering, Massachusetts Institute of Technology.	1893
LARDNER, HENRY A., State College, Pa.	Instructor in Electrical Engineering, Pennsylvania State College	1895
LYON, JOSEPH P., New York, N. Y.	Assistant Engineer, Erie Railroad Company	1894
McCOLL, JAY R., Knoxville, Tenn.	Superintendent of Mechanical Department, University of Tennessee	1894
McKISSICK, ANTHONY F., Auburn, Ala.	Professor of Electrical Engineering, Alabama Polytechnic Institute.	1897
McNAIR, FRED W., Houghton, Mich.	Professor of Mathematics and Physics, Michigan College of Mines	1897
McRAE, AUSTIN L., St. Louis, Mo.	Consulting Electrical Engineer	1894
MAGOWAN, CHARLES S., Iowa City, Iowa.	Assistant Professor of Civil Engineering, State University of Iowa	1896
MAGRUDER, WILLIAM T., ... Columbus, Ohio.	Professor of Mechanical Engineering, Ohio State University	1893
MARBURG, EDGAR, Philadelphia, Pa.	Professor of Civil Engineering, University of Pennsylvania	1894
MARSTON, ANSON, Ames, Iowa.	Professor of Civil Engineering, Iowa Agricultural College	1894
MARSTRAND, OTTO J., New York, N. Y.	Civil Engineer, No. 9 West 107th St.	1894
MARVIN, FRANK O., Lawrence, Kans.	Professor of Civil Engineering, University of Kansas.	1893

Name and Address.	Title.	Date of Membership.
MARX, CHARLES D., Stanford University, Cal.	Professor of Civil Engineering, Leland Stanford Junior University	1893
MARX, CHRISTIAN W., Columbia, Mo.	Professor of Mechanical Engineering, Missouri State University	1894
MATHER, THOMAS W., New Haven, Conn.	Principal, Boardman Manual Training High School.	1894
MATHEWS, HUBERT B., Brookings, S. Dak.	Professor of Physics, South Dakota Agricultural College	1896
MAURER, EDWARD R., Madison, Wis.	Assistant Professor of Theoretical and Applied Mechanics, University of Wisconsin	1897
MEES, CARL L., Terre Haute, Ind.	President, Rose Polytechnic Institute	1894
MENDENHALL, THOMAS C., Worcester, Mass.	President, Worcester Polytechnic Institute	1895
MERRIMAN, MANSFIELD, South Bethlehem, Pa.	Professor of Civil Engineering, Lehigh University	1893
MORLEY, FRED, Lafayette, Ind.	Professor of Civil Engineering, Purdue University	1896
MUNROE, HENRY S., New York, N. Y.	Professor of Mining, Columbia University	1893
MURKLAND, CHARLES S., Durham, N. H.	President, New Hampshire College of Agriculture and the Mechanic Arts	1894
NAGLE, JAMES C., College Station, Tex.	Professor of Civil Engineering and Physics, Agricultural and Mechanical College of Texas	1897
NEFF, FRANK H., Cleveland, Ohio.	Assistant Professor of Civil Engineering, Case School of Applied Science	1895
ORDWAY, JOHN M., New Orleans, La.	Professor of Applied Chemistry, Acting Professor of Civil Engineering, Tulane University	1894
OSTRANDER, JOHN E., Amherst, Mass.	Professor of Mathematics and Civil Engineering, Massachusetts Agricultural College	1894
OWENS, ROBERT B., Lincoln, Neb.	Professor of Electrical and Steam Engineering, University of Nebraska	1894
PATTERSON, GEORGE W., JR., Ann Arbor, Mich.	Assistant Professor of Physics, University of Michigan	1896
PEABODY, CECIL H., Boston, Mass.	Professor of Marine Engineering, Massachusetts Institute of Technology.	1894

Name and Address.	Title.	Date of Membership.
Pence, William D., Urbana, Ill.	Assistant Professor of Civil Engineering, University of Illinois.	1895
Porter, Dwight, Boston, Mass.	Professor of Hydraulic Engineering, Massachusetts Institute of Technology.	1893
Porter, J. Madison, Easton, Pa.	Professor of Civil Engineering, Lafayette College	1893
Pupin, Michael I., New York, N. Y.	Adjunct Professor of Mechanics, Columbia University,	1895
Randolph, Lingan S., Blacksburg, Va.	Professor of Mechanical Engineering, Virginia Polytechnic Institute	1894
Raymond, William G., Troy, N. Y.	Professor of Geodesy and Road Engineering, Rensselaer Polytechnic Institute.	1893
Reber, Louis E., State College, Pa.	Professor of Mechanical Engineering, Pennsylvania State College	1893
Rice. Arthur L., Brooklyn, N. Y.	In charge of Departments of Steam Engineering and Electricity, Pratt Institute	1894
Richards, Charles R , Lincoln, Neb.	Professor of Practical Mechanics and Director of the School of Mechanic Arts,.. University of Nebraska	1895
Richards, Robert H., Boston, Mass.	Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology.	1895
Richter, Arthur W., Madison, Wis.	Assistant Professor of Steam Engineering, University of Wisconsin	1894
Ricker, Nathan C., Urbana, Ill.	Dean of College of Engineering, University of Illinois	1894
Ricketts, Palmer C., Troy, N. Y.	Director, Rensselaer Polytechnic Institute	1893
Riggs, Walter M., Clemson College, S. C.	Instructor in Electrical Engineering, in charge of Electrical Laboratories, Clemson Agricultural College	1897
Ripper, William, Sheffield, England.	Professor of Engineering and Principal, The Technical School	1893
Ritter, C. Wilhelm, Zürich, Switzerland.	Professor of Civil Engineering, Federal Swiss Polytechnic	1893
Robbins, Arthur G., Boston, Mass.	Assistant Professor of Civil Engineering, Massachusetts Institute of Technology.	1894
Robinson, Frederic H., Newark, Del.	Professor of Civil Engineering, Delaware College	1894

Name and Address.	Title.	Date of Membership.
Robinson, Stillman W., ... Columbus, Ohio.	Mechanical Engineer and Expert...........	1893
Rosebrugh, Thomas R.,.... Toronto, Ontario.	Lecturer in Electrical Engineering, School of Practical Science	1896
Sackett, Robert L.,......... Richmond, Ind.	Professor of Applied Mathematics and Astronomy, Earlham College................	1893
Schuerman, William H.,.. Nashville, Tenn.	Professor of Civil Engineering, Vanderbilt University, ...	1895
Sedgwick, William T.,..... Boston, Mass.	Professor of Biology, Massachusetts Institute of Technology.	1896
Shepardson, George D., .. Minneapolis, Minn.	Professor of Electrical Engineering, University of Minnesota	1895
Sholl, Jacob M.,.............. Hobart, Ind.	Civil Engineer..................................	1893
Smart, James H................ Lafayette, Ind.	President, Purdue University	1896
Smart, Richard A., ... Lafayette, Ind.	Instructor in Engineering Laboratory, Purdue University,.........................	1896
Smith, Harry E............... Minneapolis, Minn.	Assistant Professor of Mechanical Engineering, University of Minnesota......	1895
Smith, Herbert S. S.,....... Princeton, N. J.	Assistant Professor of Civil Engineering, Princeton University	1894
Snow, Charles H.,............ New York, N. Y.	Dean of School of Civil Engineering, New York University......................	1895
Solberg, Halvor C.,......... Brookings, S. D.	Professor of Mechanical Engineering,...... South Dakota Agricultural College,...	1894
Spalding, Frederick P.,... Ithaca, N. Y.	Assistant Professor of Civil Engineering, Cornell University	1893
Spangler, H. W............... Philadelphia, Pa.	Professor of Mechanical Engineering, University of Pennsylvania	1893
Sperr, Frederick W.,...... Houghton, Mich.	Professor of Civil and Mining Engineering, Michigan College of Mines...............	1896
Springer, Frank W.,. ...... Minneapolis, Minn.	Instructor in Electrical Engineering, University of Minnesota..................	1896
Staley, Cady,.................. Cleveland, Ohio.	President, Case School of Applied Science.........	1894
Stanwood, James B.,........ Cincinnati, Ohio.	Director, Technical School of Cincinnati..........	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
STEWART, CLINTON B., Chicago, Ill.	Civil Engineer, 2501 Magnolia Ave	1894
STEWART, LEWIS B., Toronto, Ontario.	Lecturer in Surveying, School of Practical Science	1897
STOUT, OSCAR VAN P., Lincoln, Neb.	Associate Professor of Civil Engineering, University of Nebraska	1894
STRATTON, SAMUEL W., Chicago, Ill.	Associate Professor of Physics, University of Chicago	1893
STUBBS, JOSEPH E., Reno, Nev.	President, Nevada State University	1897
SWAIN, GEORGE F., Boston, Mass.	Professor of Civil Engineering, Massachusetts Institute of Technology.	1893
TALBOT, ARTHUR N., Champaign, Ill.	Professor of Municipal Engineering, University of Illinois	1893
TAYLOR, WILLIAM D., Baton Rouge, La.	Professor of Physics and Engineering, Louisiana State University	1894
THOMAS, ROBERT G., Charleston, S. C.	Professor of Mathematics and Engineering, South Carolina Military Academy	1894
THORNBURG, CHARLES L., South Bethlehem, Pa.	Professor of Mathematics, Lehigh University	1894
THURSTON, ROBERT H., Ithaca, N. Y.	Director of Sibley College, Cornell University	1893
TIMMERMAN, ARTHUR H., Rolla, Mo.	Professor of Physics, School of Mines and Metallurgy, University of Missouri	1894
TOWLE, WILLIAM M., State College, Pa.	Assistant Professor of Practical Mechanics, Pennsylvania State College	1895
TRAMMEL, ROBERT J.., Auburn, Ala.	Instructor in Mechanical Department, Alabama Polytechnic Institute,	1896
TURNEAURE, FREDERICK E., Madison, Wis.	Professor of Bridge and Hydraulic Engineering, University of Wisconsin	1894
TYLER, HARRY W., Boston, Mass.	Professor of Mathematics, and Secretary, Massachusetts Institute of Technology	1894
UNWIN, WM. CAWTHORNE.. London, England.	Professor of Engineering, City and Guilds of London Central Institution	1893
VAN DAELL, ALPHONSE N., Boston, Mass.	Professor of Modern Languages, Massachusetts Institute of Technology.	1897
VAN ORNUM, J. L., Newburgh, N. Y.	Civil Engineer	1895

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
VEDDER, HERMAN K., Agricultural College, Mich.	Professor of Mathematics and Civil Engineering, Michigan State Agricultural College	1894
VOIT, ERNST, Munich, Bavaria.	Professsor of Physics and Electricity, Koenigliches Polytechnikum	1894
WADDELL, J. A. L., Kansas City, Mo.	Consulting Bridge Engineer	1893
WADSWORTH, JOEL E., Middletown, Conn.	Civil Engineer	1895
WADSWORTH, M. EDWARD, Houghton, Mich.	President, Michigan College of Mines	1895
WAGNER, JOHN R., Drifton, Pa.	Superintendent of Motive Power, D., S. & S. R. R.	1894
WALDO, CLARENCE A., Lafayette, Ind.	Professor of Mathematics, Purdue University	1897
WALKER, ELTON D., Schenectady. N. Y.	Instructor in Engineering, Union College	1895
WEBB, HOWARD S., Orono, Me.	Instructor in Mechanical Engineering, University of Maine	1897
WELLS, JAMES H., Lexington, Ky.	Assistant Professor of Mechanical Engineering, Kentucky Agricultural and Mechanical College,	1897
WERNICKE, PAUL, Lexington, Ky.	Professor of Modern Languages, Kentucky Agricultural and Mechanical College,	1897
WHIPPLE, GEORGE C., Brooklyn, N. Y.	Biologist, Department of Public Works	1896
WHITE, GEORGE H., Worcester, Mass.	Professor of Civil Engineering, Worcester Polytechnic Institute	1896
WHITNEY, NELSON O., Madison, Wis.	Professor of Railway Engineering, University of Wisconsin	1893
WILCOX, RALPH M., South Bethlehem, Pa.	Instructor in Civil Engineering, Lehigh University	1894
WILLETT, JAMES R., Chicago, Ill.	Architect, 434 Jackson Boulevard	1896
WILLIAMS, SYLVESTER N., Mt. Vernon, Iowa.	Professor of Civil Engineering, Cornell College	1893
WILLISTON, ARTHUR L., Columbus, Ohio.	Director of Industrial Department, Ohio State University.	1897
WILMORE, JOHN J., Auburn, Ala.	Professor of Mechanical Engineering, Alabama Polytechnic Institute	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
WING, CHARLES B., ... Stanford University, Cal.	Professor of Structural Engineering, Leland Stanford Junior University....	1895
WOODWARD, CALVIN M.,.. ... St. Louis, Mo.	Professor of Applied Mechanics, and Dean of Faculty of Pure Science, Washington University....................	1894
WOODWARD, ROBERT S.,...... New York, N. Y.	Professor of Mechanics, Columbia University........................	1893
WRIGHT, CHARLES H. C., ... Toronto, Ontario.	Lecturer in Architecture, School of Practical Science	1897
ZIWETT, ALEXANDER, ... Ann Arbor, Mich.	Assistant Professor of Mathematics, University of Michigan....................	1897

DISTRIBUTION OF MEMBERS.

Alabama	6	Michigan	9	Tennessee	4
California	4	Minnesota	15	Texas	2
Colorado	3	Mississipi	1	Vermont	2
Connecticut	4	Missouri	10	Virginia	2
Delaware	1	Nebraska	4	West Virginia	3
Idaho	1	Nevada	1	Wisconsin	8
Illinois	12	New Hampshire	4	Wyoming	1
Indiana	13	New Jersey	4	Distr. of Columbia	1
Iowa	4	New York	24	Canada	5
Kansas	2	North Dakota	1	England	4
Kentucky	3	Ohio	10	France	1
Louisiana	3	Pennsylvania	17	Switzerland	1
Maine	5	Rhode Island	1	Germany	2
Maryland	2	South Carolina	2		
Massachusetts	22	South Dakota	2	Total	226

37 States, the District of Columbia, Canada, and 4 European Countries.

PAST OFFICERS.

Special Committee for Division E, (Engineering Education), World's Engineering Congress, 1893.

IRA O. BAKER, Chairman; HENRY T. EDDY, Vice-Chairman;
WM. R. HOAG, Secretary; C. FRANK ALLEN, Secretary, *pro tem*;
MORTIMER E. COOLEY, SAMUEL W. STRATTON,
STORM BULL.

PRESIDENTS.

DE VOLSON WOOD,* 1893-4;
GEORGE F. SWAIN, 1894-5;
MANSFIELD MERRIMAN, 1895-6;
HENRY T. EDDY, 1896-7.

VICE-PRESIDENTS.

SAMUEL B. CHRISTY, GEORGE F. SWAIN, 1893-4;
ROBERT H. THURSTON, FRANK O. MARVIN, 1894-5;
FRANK O. MARVIN, CADY STALEY, 1895-6;
JOHN GALBRAITH, JOHN M. ORDWAY, 1896-7.

TREASURERS.

STORM BULL, 1893-5; JOHN J. FLATHER, 1895-7.

SECRETARIES.

JOHN B. JOHNSON, 1893-5; C. FRANK ALLEN, 1895-7.

MEMBERS OF PREVIOUS COUNCILS.

Terms of Office Expired in 1894.

M. E. Cooley, H. T. Eddy, W. F. M. Goss,
W. R. Hoag, S. W. Robinson,
H. W. Spangler, R. H. Thurston.

Terms of Office Expired in 1895.

H. T. Bovey, W. H. Burr, O. H. Landreth,
Mansfield Merriman, W. G. Raymond,
G. F. Swain, De Volson Wood.

Terms of Office Expired in 1896.

I. O. Baker, Storm Bull, S. B. Christy,
John Galbraith, J. B. Johnson,
F. O. Marvin, C. D. Marx.

Terms of Office Expired in 1897.

H. T. Eddy, J. J. Flather, J. P. Jackson,
Albert Kingsbury, L. S. Randolph,
S. W. Robinson, R. H. Thurston.

* Died, June 27, 1897.

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education.

---

1. Name.—This organization shall be called the Society for the Promotion of Engineering Education.

2. Members.—Members of the Society shall be those who occupy, or have occupied, responsible positions in the work of engineering instruction, together with such other persons as may be recommended by the Council.

The name of each candidate for membership shall be proposed in writing to the Council by two members to whom he is personally known. Such names, if approved by the Council, shall be voted on by the Society at the annual meetings.

3. Officers.—There shall be a President, Two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year. They shall be chosen by vote of the members at the annual meeting.

4. Council.—The Council of this Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The officers and the past Presidents of the Society shall be members of the Council, *ex-officiis*.

Any member of this Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

5. Fees and Dues.—The admission fee shall be three dollars, and the annual dues three dollars, payable at the time of the annual meeting; there shall be no annual dues, however, for members residing outside of North America.* Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the proceedings, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who shall be in arrears more than two years and shall have been duly notified by the Secretary, shall be thereby dropped from the roll, excepting such arrearage shall be paid previous to the next ensuing annual meeting; and no such member shall be restored until he has paid his arrears.

6. Meetings.—There shall be a regular meeting occurring at the time and place of the meeting of the American Association for the Advancement of Science, or of some one of the National Engineering Societies, or otherwise as the Council may determine.

7. Publication. —The proceedings of the Society, and such papers or abstracts as may be approved by the Council, shall be published as soon as possible after each annual meeting.

8. Amendments.—This Constitution may be amended by a two-thirds vote at any regular meeting, after action thereon by the Council.

Rules Governing the Council.

First. The officers of the Society shall constitute a committee to arrange the time and place of the annual meeting, and also to prepare a program for the same.

Second. The reading of papers shall be limited to fifteen minutes each, and abstracts of the same of about 300 words or less shall be printed when practicable and distributed in advance to the members.

Third. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

---

* This clause was added at the last meeting of the Society. Notice has been given of a motion to reconsider it at the next meeting.—Editors.

PROCEEDINGS.

MONDAY, AUGUST 16, 1897.

MORNING SESSION, 9:30 O'CLOCK.

The fifth annual meeting of the Society for the Promotion of Engineering Education was held at the School of Practical Science, Toronto, Ontario, immediately preceding the meeting of the British Association for the Advancement of Science.

The meeting was called to order by the President, Henry T. Eddy, and the reports of the Secretary and the Treasurer were immediately read and were accepted. Professors H. W. Tyler and Arthur Beardsley were appointed Auditing Committee. President Eddy briefly referred to the recent death of Professor De Volson Wood, the first president of the Society; Professor J. B. Johnson followed with appropriate remarks and moved that a committee be appointed to prepare a memorial to be printed in the proceedings as an acknowledgment of Professor Wood's valuable services to Engineering Education. The motion was seconded at some length by Professor R. L. Sackett and carried, and the President appointed as this committee Professor J. B. Johnson, William Kent, and Professor R. S. Woodward.

Library
N. C. State College

The election of new members was taken up, and the following, whose applications had been approved by the Council, were elected members: George B. Frankforter, Michael T. J. Fullan, Winder E. Goldsborough, Abram W. Harris, Henry H. Kyser, Preston A. Lambert, Burton S. Lanphear, Anthony F. McKissick, Fred W. McNair, James C. Nagle, Walter M. Riggs, Alphonse N. van Daell, Howard S. Webb, James H. Wells, Arthur L. Williston.

It was voted that Section 5 of the Constitution be amended by adding at the end of the first sentence "there shall be no annual dues, however, for members residing outside of North America" so that this sentence shall read, "The admission fee shall be three dollars, and the annual dues three dollars, payable at the time of the annual meeting; there shall be no annual dues, however, for members residing outside of North America." The amendment received a two-thirds vote after favorable action by the Council.*

It was voted that the President and Secretary be authorized to extend to members of the British Association for the Advancement of Science present in Toronto an invitation to attend our meetings.

The literary exercises opened with the reading of the annual address by President Henry T. Eddy.

The paper of Professor W. H. P. Creighton on "Methods of Teaching" was then read and was discussed by Professors Allen, Gray, and Eddy. This was followed by the paper on "The Calculus for Engineering Students" by Professor F. W. McNair, which was read by Professor Kidwell and discussed by Professors Johnson, Eddy, Kidwell, Ordway, Tyler, Sackett, Bull, Gray, Allen, and Ostrander.

---

* Notice has been given of a motion to reconsider this action at the next meeting of the Society.—EDITORS.

The meeting then adjourned to the evening session.

Excursions were made in the afternoon to the power house of the Street Railway Company and to the Toronto Water Works.

EVENING SESSION, 7:30 O'CLOCK.

The exercises of the evening opened with the reading, by the Secretary, of the paper of Professor Hans Bunte on "The Influence of Scientific Research upon the Development of Chemical Technology;" this was immediately followed by the paper on "Chemical Engineering" by Professor J. M. Ordway. The discussion which followed, applied to both papers, and Professors Johnson, Eddy, Bull, Kidwell, Tyler, Wernicke, McMahon, Magruder, and Ordway joined in the discussion.

Then followed Professor J. J. Flather's paper on "The Teaching of Machine Design," with the discussion by Professors Ordway, Bull, Magruder, Kidwell, and Flather.

The paper on "The Efficiency of Technical as Compared with Literary Training" by Professor T. C. Mendenhall was then read and was discussed by Professors Murkland, Eddy, Allen, Kidwell, Mees, Lambert, Galbraith, and Waldo.

The exercises of the evening closed with the paper by Professor A. N. van Daell on "A Course in French and German for Engineers" with the discussion by Professors Wernicke, Flather, and Allen.

TUESDAY, AUGUST 17, 1897.

MORNING SESSION, 9:30 O'CLOCK.

The Society proceeded at once to the election of new members, and the following were elected, their applications having been approved by the Council: Edmund A. Engler, Edward R. Maurer, Lewis B. Stewart, Joseph E. Stubbs, Clarence A. Waldo, Paul Wernicke, Charles H. C. Wright, Alexander Ziwett.

Professors Beardsley, Bull, and Constant were appointed a committee to make nominations for officers and council, to report on Wednesday morning.

The literary exercises opened with a continuation of the discussion on the paper by Professor Mendenhall, and in this Professors Johnson, Galbraith, Allen, Kidwell, Mees, Murkland, Ordway, and Tyler took part.

The paper by Professor C. D. Marx, "At what Point should Students Engage in Specific Reseach, and how much Aid should they Receive from the Professor," was then read and briefly discussed.

The abstract of the paper "To what Extent should Metallurgy be Taught in Mechanical Engineering Courses," by Professor M. E. Cooley, was read, and was discussed by Professors Ordway and Flather, after which the meeting adjourned.

EVENING SESSION, 7:30 O'CLOCK.

The evening session opened by the reading of the paper of Professor C. M. Woodward on "Manual Training for Artisans" which was at once followed by the paper on "Manual Training in Public High

Schools," by Professor T. W. Mather. The two papers were discussed together, and Professors Johnson, Ordway, Eddy, Allen, Waldo, and R. C. Carpenter took part in the discussion.

The Report of the Special Committee on Entrance Requirements then came up for consideration, and a verbal report of progress was made by Professor H. W. Tyler, of the Committee. The report was accepted, and it was further voted that the recommendations of the Committee be adopted and that there be appointed a "Standing Committee on Entrance Requirements for Engineering Colleges," whose membership shall be the same as that of the previous special committee, and that this Standing Committee be charged with the execution of the recommendations as shown on pages 172 and 173 of Volume IV., of the Proceedings.

The paper by Professor C. S. Murkland on "Agricultural Colleges; their Function with Relation to Engineering," was read by the author and discussed by Professors Aldrich, Mees, and Bull, after which the meeting adjourned.

WEDNESDAY, AUGUST 18, 1897.

MORNING SESSION, 9:30 O'CLOCK.

The morning session opened with literary exercises. Professor H. S. Monroe's paper on "Elective Studies in Technical Courses" was read and fully discussed by Professors Eddy, Allen, Sackett, Johnson, Kidwell, R. C. Carpenter, Ordway, and Greenhill. The paper by Professor R. C. Carpenter on "Engineering Laboratory Courses" was read by the author and discussed by Professors Eddy, Johnson, and Bull. The next paper read was "A Course of Study in Electrical Engineering" by Professor R. B. Owens. This was followed by "Graduation Theses; their Preparation, Form and Preservation" by Professor I. O. Baker, the discussion on the latter being by Professors Eddy, Kidwell, Caldwell, Mees, R. C. Carpenter, Bull, Flather, and Wernicke.

The report of the Special Committee on Uniformity of Symbols was then taken up. Professors Johnson and Galbraith as members of the committee made verbal explanations touching the report, which was then discussed, Professors Greenhill, Woodward, Unwin, Macfarlane, and Caldwell taking part in the discussion. It was voted that the report be accepted and the committee discharged, and that the question of further action in the matter of symbols be referred to the Council with power to act.

Francis C. Caldwell was elected a member of the Society, his application having been favorably acted upon by the Council.

The Auditing Committee reported the accounts of the Treasurer to be correct.

The Nominating Committee presented its report and the following officers and members of the Council were elected:

President: John B. Johnson, Washington University.

Vice-Presidents: Thomas C. Mendenhall, Worcester Polytechnic Institute; Harry W. Tyler, Massachusetts Institute of Technology.

Treasurer: John J. Flather, Purdue University.

Secretary: Albert Kingsbury, New Hampshire College of Agriculture and the Mechanic Arts.

Council: Storm Bull, University of Minnesota; L. G. Carpenter, Colorado State Agricultural College; Albert Kingsbury, New Hampshire College of Agriculture and the Mechanic Arts; F. O. Marvin, University of Kansas; R. B. Owens, University of Nebraska; R. L. Sackett, Earlham College; R. H. Thurston, Cornell University.

The Society then passed a vote of thanks to Hon. George W. Ross, Minister of Education, for the use of the Buildings of the School of Practical Science, and to President and Mrs. Loudon for the courtesies received at their hands, after which the meeting adjourned.

REPORT OF THE SECRETARY.

The fact that this Society is entering upon its fifth year with unabated vigor, is more definite evidence of assured success than any statement which properly enters into the report of your Secretary. The Society now numbers more than two hundred members, after making allowance for losses by withdrawal and by death. In another direction, the financial side, it has been found possible to stimulate the sale of proceedings to libraries of Engineering Colleges, and to public libraries, to an extent that has allowed the deficit of last year to become largely reduced although not altogether wiped out. In no direction does there appear to be any hindrance to a continued, or even an increasing career of usefulness, which has not been confined to its own members, but has invaded the domain of the preparatory schools through the active inquiries and the valuable reports of our Committee on Entrance Requirements for Engineering Colleges.

Attention is called to the fact that this Society is organized and adapted to reach all who are connected with the work of Engineering Education. An inspection of the programs will show an increasing tendency to consider questions of general interest to Engineering Education, with whatever branch they may be connected. There is a steady increase in membership from the presidents and directors of Engineering Colleges, a fact which insures an increase of efficiency for the Society, and at the same time gives assurance that these colleges appreciate the work the Society is doing.

It is the sad duty of your Secretary to announce the death, during the past year, of three members of this Society who were men of exceptional ability, each in his special sphere.

Charles B. Brush, who died June 3, 1897, had attained high distinction as a Civil Engineer, having been a Director, and afterwards a Vice-President of the American Society of Civil Engineers. It is seldom that an engineer so actively engaged in successful practice has found opportunity for work as an educator, as did Professor Brush, who, at the time of his death, was Dean of the School of Civil Engineering of New York University.

Francis A. Walker, who died January 5, 1897, had attained distinction in many directions; in the army; in civil government in many official positions; in various bodies interested in the social and economic interests of mankind; and especially in educational work, where he had well served both city and state, although he was known most prominently as President of the Massachusetts Institute of Technology, whose advancement under his administration was so marked that his work in that capacity appeals to many as the most successful and valuable of the achievements of his very active, many-sided life.

De Volson Wood died June 27, 1897. As a writer upon mathematical and engineering subjects his reputation was well established. But it was in his career as a teacher of engineering, extending over forty years, that his best work was done, and his greatest distinction achieved. His directness, his downright honesty of thought and expression united with his ability to lead his pupils to do their best, served to grant to him a power as a teacher that few of us can hope to equal. He was by general consent selected, was elected, and served as the first President of this Society. Of his later interest in its affairs there was abundant evidence.

While it is not the function of your Secretary, and his report is not the place for formal eulogy of the dead, it is yet fitting that a simple notice should be given of those who have died during the year; and it will also be not improper to record here without special comment the deaths of Eckley B. Coxe, May 13, 1895; and of Justus M. Silliman, April 15, 1896: no formal note of these having been made in previous reports.

Your Secretary respectfully suggests that the usefulness of this Society can be promoted by bringing into membership, not only the presidents of Engineering Colleges, but also the professors of languages and other non-professional studies, and so giving opportunity for greater breadth of treatment than might come from a body with a purely engineering membership.

Respectfully submitted,

C. Frank Allen,
Secretary.

Treasurer's Report.

The Treasurer of this Society would respectfully report as follows:

The total receipts during the year 1896–1897 from various sources, as given in the itemized statement below, have been $890.55, of which $526.00 were for current dues.

It will be noted that there is a balance of $542.75 on hand, but this balance is only apparent, since there are outstanding bills (just handed to the Treasurer) amounting to $593.35 so that there is still an actual deficit of some $50.00.

The expenditures of the Society have been unusually heavy during the past year, and it is owing to these unusual expenses, and to the fact that a deficit of $132.76 existed at the close of the previous year, that the Society's finances are not in better condition.

The Treasurer would again urge upon the membership the desirability of completing their sets of the Transactions of the Society.

During the year $211.00 was received from the sale of the annual Proceedings, a large number of which have been supplied to Public Libraries and other institutions.

A condensed statement of receipts and disbursements for the year is appended herewith:

RECEIPTS.

By Sale of Transactions	$211.00
By Reprints of Authors' Papers	26.55
By Initiation Fees	90.00
By Past Dues	32.00
By Advance Dues	5.00
By Current Dues	526.00
Total	$890.55

DISBURSEMENTS.

To Unpaid Bills for Year 1895–6	$132.76
To Badges for Buffalo Meeting	5.50
To Stenographer's Services, Buffalo Meeting	90.00
To Postage	52.02
To Express and Telegrams	4.86
To Stationery	2.26
To Printing Circulars, Programs, etc.	56.75
To Discount on Checks	3.65
To Cash on Hand	542.75
Total	$890.55

August 16th, 1897.

JOHN J. FLATHER,
Treasurer.

ADDRESS BY THE PRESIDENT.

PROFESSOR HENRY T. EDDY.

On Engineering Education.

In opening the proceedings of this fourth annual meeting of the Society for the Promotion of Engineering Education, I wish first of all to congratulate the Society upon its great success thus far in accomplishing the object for which it was founded, an object fully expressed in its name. The volumes of its proceedings already published are filled with discussions and the ripe conclusions of the best thought that can be expressed to-day upon many phases of engineering education. No one who desires to become informed upon these matters can afford to neglect these volumes. It is believed that all interested in the object of our Society will find it to their advantage to unite with us.

One striking peculiarity of engineering education seems to me to lie in the fact that it has been determined so largely as to its scope and the lines of its development by the engineering colleges themselves in advance of the formulated demands of the engineering profession and of the public in general, and often indeed in opposition to such demands. Through the wisdom and foresight of these organizers of engineering education the profession of engineering has come forth during this generation into public estimation as a learned and responsible profession quite the peer of law or medicine. This is the work of the engineering colleges, and from the deliberations of this Society it is evident that they still have a large work before them. The educational institutions of our country are in a state of flux. The present movement in education is powerful. These times will be looked back to in future days as those in which mighty educational forces were inaugurated and were adapted to the needs of the nation just as it was coming to its full consciousness as one of the great family of nations, a consciousness of power and responsibility that is causing it to depart somewhat from the revered advice of Washington, which was to keep aloof from European affairs and from entanglements with the other nations of the earth and to work out its own destiny by itself. National growth and our multiplied facilities for communication have greatly modified our feeling as to this. The triumphs of the engineer in applying steam and electricity are making of one blood all nations of the earth. But the one thing that is making and will make of us a nation worthy of our heritage is our educational life. Our republican institutions, the pride of our early national life, cannot continue such except for the reinforcement and help to come from the enlarged scope of education to-day.

It has seemed to me that I could not perhaps use the short time allotted to me for this address better than in trying to summarize some of the thoughts which have appeared in the papers and discussions before this Society, which had its beginning in the Engineering Congress of the Columbian Exposition at Chicago. What I have to say is called forth by the enlarged responsibilities and new conception of the professional position of the engineer of to-day, and the course of study necessary to fit him for the responsibilities of his position.

And first of all I think I am right in saying that the demand is growing stronger that courses of engineering instruction shall be exclusively devoted to engineering, so that they shall be as completely professional in their character as are professional courses in law and medicine. This demand is not made by the general public, nor to any great extent, I think, by practitioners in the engineering profession. These are greatly impressed with the necessity the engineer has for general culture; and rightly so. The demand is one made by the engineering colleges themselves. In order to estimate the import of this demand more precisely it may be said that at present the curriculum of our average engineering college includes from 20 to 25 per cent. of culture studies such as English, French and German; from 30 to 35 per cent. of indirectly technical study, as mathematics, physics, etc.; and 50 per cent. of directly technical study.

The culture studies are of fundamental importance to the engineer. He usually obtains far too small an amount of such study before graduation. He finds himself poorly fitted in this respect for his subsequent career. His preparation in the use of language for writing and speaking has been too meagre. He finds that his professional work is not of a character to supplement his education in this particular. Yet culture studies are out of place in any engineering course with strongly marked technical tendencies. Both student and instructor feel this. The two kinds of study interfere with each other. The student cannot fix his attention on culture study while absorbed in the beginnings of technical study. Instructors in the culture studies feel the hopelessness of the task and must perforce be content with a lifeless, *memoriter* fulfilment of task work. Instructors in the technical studies are apt to be impatient at the time and attention demanded by the culture studies as more or less of an obstacle and hindrance to what is rightly regarded as the student's main work.

Under circumstances such as these it seems clear that the culture studies must soon disappear from our engineering courses. This change will doubtless come about gradually and will occur in the more fully developed courses first. It will not mean that culture studies shall be omitted from the education of the engineer. It will simply mean that he must obtain them outside of the engineering course, preferably before he enters it. The tendency on every hand is to insist more strongly than heretofore upon the culture studies as essential to the engineer. To ensure large success he must be a man of broad culture. He is to direct large enterprises as well as plan the necessary structures and machinery of the plant; and that man will succeed who, by the influence of his personality with tongue and pen, shows himself able to hold his position as the peer of other great organizers of our industrial life. The highest success is to be quickly reached as a rule only by those engineers who have had adequate preliminary education in culture studies, which is another name for the liberal arts. Such culture is now most readily and suitably attained by pursuing some part, more or less complete, of a regular college course. This will come to be regarded more and more as the best preparation for a professional course in engineering as it is now for a professional course in law and medicine.

Following the consideration of the culture studies comes that of the indirectly technical studies such as mathematics, mechanics, physics, chemistry and drawing, which at the present time occupy between one third and one fourth of the time of the average engineering course. These studies rightfully have place in the course, but the question whether the amount and quality of the work at present accomplished is entirely satisfactory, is one which has been much debated. It may be said fairly, I think, that the standard of work in mathematics, mechanics and physics has been gradually but surely advancing in all the engineering colleges, against the opposition of a large part of those engaged in engineering practice, who have been largely opposed to teaching more mathematics, etc., than they themselves were taught, saying that they have had no use for much of that which was taught them. This argument has seemed perfectly conclusive to those who have advanced it, and also to the student, who naturally finds such studies hard, and (as he thinks) much in the way of his rapidly advancing to purely technical study. This view has also often met acceptance with the technical professors who are largely in sympathy with those engaged in practice. But the argument is fallacious, as I am convinced. The contrary view has prevailed in the papers before this Society.

We are to look upon this gradual advance of the standard in mathematics, etc., as a movement which has not as yet ceased, but, on the contrary, is still in progress.

Perhaps the point of greatest difficulty, so far as mathematics is concerned, has been to have the differential and integral calculus so incorporated into the engineering courses as to really become part of the working equipment of the student. That may not have been completely accomplished as yet, but that is the standard now regarded as essential, and one which is more and more nearly attained year by year. It is my opinion that it will not be satisfactorily reached until the course in calculus includes the treatment of differential equations. This conclusion is forced upon me, not merely by the abstract consideration that physical and mechanical questions find their expression best by the use of differential equations; but the problems arising just now in the theory of alternating currents must evidently be treated on the basis of their differential equations. Heretofore it has been possible to satisfy the student as to the treatment and solution of the mechanical and physical problems in his course without special study of differential equations, though he was likely to meet a number of points that were puzzling and unsatisfactory by reason of his ignorance of that subject. But now the matter can no longer be avoided, I think, as no other treatment can give the necessary insight into the complicated phenomena which must be fully mastered to-day by the student in electricity.

Mechanics too, and physics have taken on a larger and larger significance. The principles of mechanics underlie all physical phenomena and all engineering processes. Their formal study has been found to be of increasing importance in understanding the strength and resistance of materials, the thermodynamics of steam and gas engines, turbines, electrical generators, motors, and transformers.

But the attempted mastery of those principles by the student in such a fashion as to render them a sure possession and means of attacking the technical problems he must deal with, has been a matter of great difficulty and weakness in engineering education. This is the more to be deplored because of the fundamental character of the subject, it being, as it were, the master key to unlock all doors. Perhaps the greatest step toward removing this serious difficulty will be to change somewhat the usual order of study in mechanics in our engineering colleges, and make our arrangements conform more nearly to those in vogue in England. The practice there, as I understand it, is to introduce at an early stage of the student's course a thorough drill in the elementary problems of mechanics and not postpone beginning this subject until the calculus has been studied. In case the student does not begin mechanics in earnest until he is about half through his undergraduate course, and then the subject is developed analytically with calculus demonstrations, the almost inevitable result is that the uncertainties of mechanics, taken in conjunction with an imperfect apprehension of the real purport of the newly acquired process of the calculus, form a fog so dense that it is long before the average student is sure of his bearings in the subject, and he may likely never come to a clear understanding of it, all-important as it is in its theoretical aspects. The more elementary principles of mechanics should therefore be made a sure possession of the student early in his course. The difficulties just mentioned will then have been largely obviated.

As to physics and chemistry it is unnecessary for me to explain how small are the opportunities at present offered as compared with what is desirable. The state of knowledge in these sciences is steadily advancing. Hertz waves and Röntgen rays are meeting technical applications. New knowledge must have place. The field constantly increases, and more time must be taken for such subjects. We cannot escape it. It seems impracticable to secure this by having more physics and chemistry taught in the preparatory schools. Such work is not satisfactory. It is preferable to relegate more of the pure mathematics to those schools.

We are to look in the future, as I think, for an increase in the amount and an improvement in the quality of the work in all that part of the work in our engineering courses, which, though but indirectly technical, affords the theoretical basis of the strictly technical studies of the course.

The improvement in the quality of the instruction will lie, for one thing, along the line of the illustrations and the problems employed, in seeing to it that they have to do with things tangible and in the direction of practice. This will help secure the necessary interest in theory and make it, as it should be, the basis of practice.

We now come to the consideration of those studies which are strictly and directly technical. They occupy in most engineering courses at least one half of the course. The improvements which have taken place in engineering courses have occurred more largely in this part of the work than elsewhere; but great divergence of opinion has naturally arisen as to what is best. In certain courses of mechanical engineering an excessive amount of manual training and shop work was at first introduced; inexpert opinion still lays undue emphasis upon this part of the course in mechanical and electrical engineering. But, as the true function of manual training and trades schools comes to be better understood, and their value to the community in developing handicraft and in furnishing education to the artisan as distinguished from the professional engineer, not only will such schools be well supported and greatly increased in number, but they will be sharply distinguished in the minds of all from the engineering colleges. These last are not intended to make skilled workmen, though some seem still to think so. The engineering student needs a comparatively small amount of practice in wood working which shall be especially directed toward pattern making, a short experience in the blacksmith shop and foundry, and somewhat more of metal working by hand and machine tools, together with the management of boilers and steam engines. But any effort to make prolonged exercises in these subjects take the place of more theoretical study, is an endeavor to make a workman or a foreman instead of an engineer.

The same is true of extended civil engineering field practice with instruments. It is quite possible to put too great emphasis upon it and consume more time upon it than the study warrants. The temptation to do this is strong. It must be remembered, however, that surveying is not to-day the principal occupation of most engineers. The plan of putting shop practice, field work, and other like practical parts of the course into the long vacations, has much in its favor and seems to be coming more into vogue. The student should graduate from the shop and the surveying corps as soon as he has gotten a moderately good acquaintance with tools and processes, and enter the testing laboratory. That is the true field for extended practical work in the engineering course. In it the work should be arranged with regular sets of graded exercises covering the measurement, proper records, and working out the results of tests on all the materials and processes treated in the theoretical work of the student, as well as whatever he is likely to encounter in practice or inspection. It is only by prolonged drill in testing that he can acquire the necessary basis for that professional and practical judgment which will make his opinion of value. While thus insisting on testing laboratories as the best and most important recent development of our engineering colleges as well as the most costly parts of them, it is needful to insist at the same time and with still greater emphasis on the paramount importance of the theoretic instruction in the mathematical, mechanical, and scientific principles which should furnish the core of every engineering course. This it is which engineering colleges must teach and trade-schools may entirely omit. Engineering colleges may leave out shops and laboratories. and some do so; they may omit culture studies, and have very imperfect instruction in drawing and design, without forfeiting the claim to give engineering courses of considerable value. But no engineering college can afford, at the risk of imperilling its reputation and usefulness, to neglect or slight for any length of time to put forth its best efforts to thoroughly indoctrinate its students in as complete and extended a theoretical treatment of the engineering subjects it teaches as the time at its disposal and the preparation of its students will permit. Drawing and designing, shop practice and testing, general culture and professional information all are subsidiary and auxiliary to this one thing. Engineering courses at first began with little else in them of importance to the profession than this, and by it they have proved themselves indispensible to it. It is a mistake too frequently made by practitioners deeply immersed in the details of their profession, to suppose that the most important and fruitful field of instruction is not just here.

Practice, experience, judgment, will come in time to the young engineer even if he should not have it before graduation, but study and theory he will not usually thus attain to. That must be had before graduation or the engineering college has little excuse for existence.

This being granted, the fact still remains that the ultimate success of the engineer as a professional man depends upon his character and force as a man among men, upon his culture, upon his integrity, upon his tact and social power. In other professions such qualities receive continuous culture in the practice of the profession. It is far less so with the engineer. Here then is an argument for broad preliminary culture before entering upon engineering study, but it likewise points to something with which the engineering colleges have thus far not busied themselves to any appreciable extent, but which in the future cannot be neglected in justice to the position which the profession is called to occupy. Every engineering student has the right to careful instruction in a recognized code of professional ethics which shall instruct his conscience and fortify his will, and give him a satisfying consciousness of duty done to his professional brethren, to the public and to the judge of all the earth.

Until such instruction shall take its place in our engineering courses the public can never rely upon organized professional opinion to restrain unprofessional conduct, nor can individual members of the profession be sustained in courses of right action against the demands of corporations and combinations of capital. It remains then for engineering colleges to help organize the profession and to furnish the basis of such organization in a code of professional ethics, which shall be worthy, unifying and elevating.

One step further in this direction is also of importance, namely: Provision for such instruction in the law of contracts as will enable the engineer to discharge with confidence his professional obligations and protect the interests of his employers. For it is not only necessary that he should have adequate scientific and technical knowledge to adapt the forces of nature to the projects in view, and exercise good judgment as to the best means of doing this, as well as have the ability fully and clearly to set forth his plans in a manner to carry conviction to those seeking his services; but it is also equally necessary that, when entrusted with the responsibilities of actual construction, he should be able clearly and explicitly to set forth the rights and obligations of all parties, that disputes and legal difficulties may not arise, such as often are more costly and troublesome than errors of design. The place to obtain the necessary legal knowledge of specifications and contracts is during the professional engineering course.

It has been urged by some that, since economic design is dependent upon the market price of materials, labor, and power, this subject should also find place in the engineering course, but the consensus of best opinion seems to draw the line here between education and practice. While the attention of the student should undoubtedly be drawn briefly yet pointedly to the economic limitations under which commercial work is done, the attempt to make designs under such limitations should be mostly left to the time when judgment has ripened and the complex conditions of practice are better known by experience. In fact almost no undergraduate work can usefully reproduce competitive conditions, and the attempt to do this must usually be regarded with distrust. The aim of teaching is not an object lesson under business conditions, but thorough instruction in underlying principles, especially those theoretical and scientific principles which cannot be correctly estimated by the layman.

It will be noticed in all the matters in which I have attempted to reflect the opinions which are current in the papers that have been presented to this Society and published in its proceedings, the movement and tendencies which I have sketched can be traced, all of them, to a single source, namely, to the position of influence and responsibility which the professional engineer has but recently come to occupy. That position is what it is to-day in the esteem and respect of the public, largely through the wise efforts of the managers and instructors of the engineering colleges. Their work in moulding and directing the engineering education in the future will, I am persuaded, be no less important than in the past. That such guidance shall continue to be wise, its progress healthful, and costly mistakes be avoided, will be materially assisted by the deliberations and discussions of this Society.

The valuable report of the Committee on Entrance Requirements now in your hands is an important piece of work, taking rank beside the other great educational reports upon the various phases of secondary education which have attracted such general attention during a few years past and have influenced so greatly the work of the preparatory schools as well as the requirements of the colleges.

I regard it as one happy omen that we are met to hold this meeting so early in our history here in Toronto, thereby expressing our interest in the promotion of engineering education as a branch of ap-

Library
N. C. State College

plied science confined by no geographical boundaries or limitations. Our presence here is an expression of our conviction that some of the most vital elements of human progress are to be in some measure moulded by the conclusions we shall reach in the papers which will be presented and in the discussions that will take place at this meeting. Let us then address ourselves to the work before us with the same fraternal zeal that has characterized the meetings of our Society in the past, and that in fact is singularly characteristic of that noble body of men who practice the profession of engineering, a profession whose triumphs are our pride and whose future greatness it is the object of this Society to foster.

ENGINEERING LABORATORY COURSES.

BY R. C. CARPENTER.

Professor of Experimental Engineering, Cornell University, Ithaca, N. Y.

The following paper is not intended to cover the ground with a discussion relating to the best method of teaching in an engineering laboratory, nor is it intended to give in any manner a general discussion of the best arrangement of studies in a laboratory course; on the other hand it is intended to present a brief summary of the experiments in the field of laboratory instruction which have been conducted during the last ten years in Sibley College, Cornell University. The work described is not presented as a model of its kind, but in the hope that the experience we have had in the past may be of benefit to other teachers in similar lines and furthermore that the discussion which will probably follow the paper will aid us in correcting such methods as are proved to be erroneous and assist in introducing new methods of instruction and thus strengthening the laboratory course.

The laboratory of Sibley College is intended to give instruction to students in mechanical and electrical engineering, in technical subjects relating to mechanical engineering, and also to provide an opportunity for investigation and research. The laboratory then has two functions, and in this respect I suppose it is similar to that in most institutions, one of which is purely educational, the other technical and professional. Although that feature of the laboratory which relates to investigation is one which demands the most energy on the part of the instructor and the greatest equipment on the part of the University, it will not be considered in this paper, for the reason that it is not in my opinion capable of being systematized or reduced to a course of instruction; and secondly, no individual can successfully perform investigation unless he has had a considerable previous training, both in the general theory and principles which underly the subject, and in the method of handling apparatus and making tests.

The conditions which surround every course of instruction and which determine the amount of preparation that the students have on entering, must naturally have great influence on the character of the course and must determine to a great extent the method of teaching and the character of the subjects presented; consequently what will be stated here should be discussed as especially referring to the conditions prevailing at this Institution (Cornell University), which may be characterized briefly as follows:

First, a complete system of class instruction in which the general principles relating to the technical subjects under discussion are fully explained and exemplified.

Second, a thorough system of shop training, covering practice in mechanical branches of wood working, foundry work, blacksmithing, and machine shop.

Third, the small amount of time which is available for laboratory instruction in the regular course.

All of these conditions have considerable influence on that course which can be profitably adopted, and a failure to take into account these various conditions, may, in laying out a course, seriously affect the results.

At the time of organization of the Mechanical Laboratory of Sibley College it was found that a two-hour course of instruction for junior and senior students was the longest that could be obtained without lessening the time already required for valuable studies. A two-hour course in a laboratory at Cornell University means five hours of work in the laboratory, a part of which may be devoted to the preparation of the report of the experiment. Hence the amount of time to be devoted to this subject was five hours per week during the junior and senior years. This amount of time is small, and the question at once arose as to the method which would give the student the best results and the greatest value for the minimum expenditure of time. In laying out the details of this course it was necessary to consider the special objects of the laboratory, and these may be briefly stated as follows with reference to the development of the student:

(1) Practical familiarity with apparatus.
(2) Opportunity to apply principles of engineering.
(3) Cultivation of habit of observation.
(4) Knowledge of methods of research and testing.
(5) Practice in operating engines and machines.
(6) Practice in describing results of investigations.
(7) Preparation for research and investigation.

The number of students, the number of instructors, and the amount of apparatus available should also receive serious consideration. At the time of organizing the laboratory course in Cornell University there were about 175 students ready to enter the laboratory classes, myself and one other teacher to give all the instruction, and a very limited amount of apparatus available. After reviewing the ground very thoroughly, it was decided that the only plan which could, under the circumstances, be adopted with any chance of success was to prepare a limited number of experiments, to give the student minute and detailed instruction as to methods of performing the experiment, and require him to write a full and detailed account of the experiment, performing all computations required for results and conclusions. Furthermore, in order to have the experiments of most value to the student, and illustrate the principles taught in the class room, it was deemed necessary to have them graded. This condition is somewhat antagonistic to the general plan, since, if a large class is to be kept on a limited number of experiments and these experiments performed by some individual or section of individuals each day, it is evident that the order in which the experiments are presented cannot be the same for each individual. For this scheme then it is evident that the grading must be not by individual experiment, but by groups of experiments; the experiments being so arranged that the order in any one group is entirely immaterial, but on the other hand the sequence of the groups is of vast importance; and this plan was adopted as the underlying principle and as far as possible was put in practice.

The engineering experiments and tests are generally of such character as to require the services of two or more persons in order to conduct the test and take the necessary observations. This gave an opportunity for dividing the students into sections. A section containing two students has always been preferred to one of greater number, sections being combined when it is necessary to have more than two observers; but it has not always been possible, on account of the large number of students and the limited number of instructors, to carry out this plan, and it has more frequently happened that our sections have consisted of three or four individuals rather than two.

Experience also taught us that a great saving of the teacher's energy could be made by separating into two periods the time allowed for the experiment, using one period for performing the experiment, taking the necessary observation, etc., and the other period for reducing the observations and writing up the results. This plan has always been adopted of necessity in Sibley College laboratories, where the student performs his experiment as assigned once per week, writes up the report, making necessary computations and drawing the necessary curves at his own convenience, but during the week in which his experiment was performed. The report is handed in to the instructor and is kept on file at least for the remainder of the term.

Experience proved to us that the time required for writing the report, in order to be of a character to satisfy our demands, was usually two or three times the amount allowed. On account of this some complaint was made by the poorer class of students or by those who were overworked, but very generally the students were interested sufficiently in experimental work to perform this extra labor without credit and generally in the most willing spirit.

I may mention that for six years the practice as explained has been maintained, and generally the extra work required has been performed without complaint. I doubt if students would willingly take as much extra labor without credit in any other branch of engineering study.

This willingness of the student to overload in one branch of an engineering course has generally a bad effect on his other university work and we found certain difficulties to arise owing to students neglecting other studies. To prevent this the laboratory course has recently been lengthened to three hours without increasing the number of experiments, one hour however being devoted to recitation, review and discussion of the experiment.

The question will arise to those who have given the matter thought as to whether or not the experiment should be written up in the absence of the instructor. Under our own particular conditions we have had no choice, but we have found that when the men work in groups, although each presents an individual report which is supposed to be an individual production, there is an opportunity to palm off on the instructor the brain work of a willing partner instead of his own. It is very easy to modify the condition of the experiment so that it is quite impossible for students to palm off an experiment they did not perform, unless the instructor is exceedingly careless in the matter, but it is not so easy to be certain that each person does his own share of the work. Many of the groups of two are often constituted, in spite of all precautions to the contrary, on the same principle as the farmer's well matched team, of which he said "that one horse was willing to do the work and the other was willing he should." Indeed, I have often noticed, in the formation of college friendships which are maintained throughout life, that a very strong man, both mentally and physically, will often be joined to a comparatively weak man, one supplying the energy and the mental activity, the other acting as a willing satellite or assistant; the joint production of the two being perhaps good average work. It is very difficult to get two stirring, active, energetic men to work together harmoniously, and, as harmony is the principal element of all success, we have found it best generally to permit the student as far as possible to select his own partner. For the first few years of the course the students' reports were written in blank books of sufficient size to hold the reports for a year; a sample book of this character is exhibited. This practice was open to the objection that the book had to be returned to the student after the instructor examined each experiment and this gave an opportunity for copying from other students, which the instructors thought was not conducive to the best work.

This has led to a change in the form of reports of experiments; at present each student is required to present his report of each experiment bound in manilla covers of a certain form, and these are not returned until the work for the term is completed.

The extension of the course to three hours has permitted the instructors to hold an individual examination covering the experimental work, and this, to a great extent, has prevented cribbing, or at least enabled us to identify the individual work of the student. I do not mean to insinuate that we have discovered some method of making a dishonest student honest or of detecting him in dishonesty; on the contrary, it is my experience that such a man will invent methods that will evade any requirement, and I have ceased to worry over the possible consequence to a student who pawns off some one else's efforts for his own. Such a man is in reality cheating no one but himself, and, while it is now and then possible for him to obtain a mark or rank which is not deserved, on the whole his dishonest efforts will be punished at some time by a failure to succeed. I hardly believe that it is my duty to spend any great amount of time as a detective; but on the other hand, I do believe that it is my duty to give every possible opportunity for those who desire to improve themselves. Fortunately, nineteen men out of twenty are above reproach in this regard; and hence, while the method of instruction presented is weak in the way described, very excellent results have been obtained in nearly every case, and we have found it a practical success.

In order to give the students minute instruction as to the methods of performing an experiment, I prepared a text-book* which has been used with excellent success and in which are given the methods to be pursued, also suggestions and hints relating to the experiment. This work has been used quite extensively in other engineering schools, and the fifth edition is now in course of preparation. We have required the student to study his experiment before appearing in the laboratory, and we have also required him to have passed the necessary preliminary studies so that he is supposed to undertake the experimental work with a full knowledge of the principles and the general methods to be applied.

---

* Experimental Engineering. New York : J. Wiley's Sons.

We have not required the student to make the manual preparations, *i. e.*, the shopwork for the experiment, except so far as obtaining the necessary apparatus and attaching and adjusting it. There are many reasons for this; the first and principal one is the lack of time. For instance, if a student were to make an engine test and do the mechanical work incident to a preparation for the test, that single experiment would take a complete term. The result would be that with such a system the number of experiments which could be taken would be so limited that very few of the objects of the laboratory as an undergraduate source of instruction would be satisfied. A second reason, which is of considerable importance under the conditions existing in Sibley College, is that the student is given the necessary shop instruction and training for this kind of work in another department, and it is not necessary that he have practice in such work in the experimental department. A third reason is the absence of the necessary tools for the work of a considerable number of students at any time.

Regarding the nature of the experiments, these must of course be varied with the special nature of instruction and with the equipment at hand. The course of experiments is, as previously mentioned, divided into groups, each group being so arranged that the order of experiments in that group is immaterial. In the first group of experiments are placed the study of apparatus used in investigation, and simple experiments which can be considered primary or elementary. For Sibley College, the apparatus used consists of measuring instruments of various forms, steam gauges, steam-engine indicators, thermometers, pyrometers, testing machines, etc.; and the experiment, in group one, consists of a study of the structure of the apparatus, practice in its use, and a test of its accuracy. Usually eight experiments are placed in the group. In the second group are placed a series of simple experiments which employ the apparatus previously studied. Efficiency tests of machinery are undertaken just as soon as the student is prepared for them. The following table shows the experiments which were performed in the regular undergraduate course during the past year, and indicates what experiments now constitute the course in "Methods of Testing" in the mechanical laboratory of Sibley College. This is, however, subject to changes each year.

SENIOR SCHEDULE.

Fall.	*Winter.*
Hirn's Analysis.	Hirn's Analysis.
Compound Engine Test.	Triple Expansion Corliss Engine.
Injector Test.	Ice Machine.
Boiler Test.	New York Air Compressor.
Governor Test.	Belt Test.
Rider Hot Air Engine Test.	Valve Setting.
Otto Gas Engine Test.	Ericsson Hot Air Engine.
Oil Engine Test.	Nash Gas Engine.

Spring.—Thesis work and investigation.

JUNIOR SCHEDULE.

Fall.	*Winter.*
Tension Test of Cast Iron.	Tension Test of Wrought Iron.
Transverse Test.	Torsion Test.
Steam Gauge Calibration.	Steam Pump Test.
Indicator Spring Calibration.	Barrel Calorimeter.
Nozzle and Orifice Calibration.	Separating and Throttling Calorimeter.
Flue Gas Analysis.	Boiler Test.
Planimeter Calibration.	Weir Test.
Use of Calculating Instruments.	Morin Dynamometer Calibration.
Viscosity of Lubricants.	Friction of Lubricants.

JUNIOR TEST.

Spring.

Compression Test.
Coal Calorimetry.
Thermometer Calibration.
Simple Engine Test.
Webber Dynamometer.
Hydraulic Ram.
Pelton Wheel.

The number of experiments which can be taken must depend upon the number of students and upon the amount of apparatus. Apparatus or machines of an inferior quality can often be used for tests, the object of which is simply the study of methods and of writing reports ; hence a collection of apparatus suitable for a great variety of efficiency tests can be obtained with little expense. A course in investigation and research must naturally consist of a series of isolated experiments, each of which must be considered independent from other investigations. During the last year from 250 to 275 students were registered in the undergraduate courses of Sibley College and from 50 to 75 students in the more advanced work of research and investigation. For this latter work only such students were allowed to register as had the necessary preparation in the undergraduate course or were qualified by graduating in some previous course.

The corps of instruction at present consists of myself and five instructors, each of whom takes charge of the experiments in a certain department, the departments being organized as follows:

(1) Testing materials.
(2) Hydraulic machinery and lubrication.
(3) Dynamometers.
(4) Hot air, gas, and oil engines.
(5) The experimental engine and refrigeration.
(6) Investigation and research.

The department has the services of a mechanician, a mechanic skilled in pipe fitting, and a janitor.

In the foregoing paper the writer has undertaken merely to outline the methods which have been found at least reasonably successful in the Sibley College laboratories, and to describe the peculiar conditions which lead to the development of the method of instruction pursued.

No attempt is made to show that such a method would be the best to be pursued by every college under its peculiar environment. It is a method, however, which has proved to give students a large amount of instruction in practical engineering processes and methods, in an extremely limited time. It is a method which is also economical of the time of the instructor and of university funds and apparatus, and in our particular case it is the result of the evolution due to peculiar conditions mentioned.

Were the time of a student unlimited, and could an instructor devote a large amount of time, an ungraded course without specific directions might be successful; and such conditions may prevail, and are doubtless paramount in some institutions, in which case better results will be obtained by a different course.

NOTE.—The Mechanical Laboratory of Sibley College was planned by Dr. R. H. Thurston, who had, previous to his appointment in Cornell University, successfully conducted several laboratory classes and had carried out many notable investigations. Entering Sibley College in 1885, the laboratory plan of education was outlined, and as soon as possible put into operation.

The writer was appointed to Cornell University in 1890 and the scheme of instruction presented was adopted with advice and approval of the Director.

DISCUSSION.

PROFESSOR JOHNSON thought that the greatest value of such a paper as this was in giving to others the benefit of a large amount of successful experience—successful in the matter of the number of instructors, the number of students and the quantity of apparatus. In fact, we all look to two or three of our largest institutions for just such fruits as these. He hardly thought the paper needed discussion. He was sure the members were all delighted to have the results of Professor Carpenter's experience and work, and it would be very valuable to all of them in their own work. He thought the Society was under great obligations to Professor Carpenter for taking so much of his busy time to prepare this paper and for coming here to deliver it.

President Eddy said they would certainly appreciate this paper highly when able to study it and compare it with their own work. These papers when printed in the Proceedings were of paramount importance to those engaged in engineering instruction.

A COURSE OF STUDY IN ELECTRICAL ENGINEERING.

BY R. B. OWENS,

Professor of Electrical and Steam Engineering, The University of Nebraska,
Lincoln, Neb.

My object in presenting the following paper is to call attention to the difficulty with which instruction in Electrical Engineering is kept abreast of the current development of the subject, and to point out certain expedients found useful in this connection in a school distant from the larger industrial centers, and in maintaining a sustained interest on the part of the student and fitting him more quickly for the responsibilities of engineering work.

The unparalleled growth of electrical industries in the past decade, and their present increasing rate of development, make the task of bringing the school work to correspond to best engineering practice seem an almost hopeless one. But unless such a correspondence does obtain, an injustice is done the student, at least if he is allowed to believe that the work he is doing is strictly professional work similar to the work done in the best schools of law and medicine.

To be sure, it is contended by some that it is only within the province of the school to impart the broader principles that underlie engineering in general, and its several branches in particular; but a careful study of the possibilities of technical training very clearly shows that much of the time now spent by the student in learning to apply general principles might be saved if, in the last year or two of study, he were brought into closer relation with the methods and practice of our more successful makers and best constructing engineers. I do not wish to be understood as saying that all the details of dynamo manufacture, street railway construction, etc., can even be touched upon in a course in electrical engineering. Such details vary so rapidly as to make it impossible for a school to follow them, even if it were advisable. However, it is generally known outside of the schools that little information of real value, relating, for instance, to dynamo design (not electric and magnetic theory on the behavior of particular dynamo machines) is obtainable in the greater number of courses in electrical engineering in this country. Such a condition when looked at fairly is readily explained. The men who to-day are successful designers of dynamo machinery and builders of electric lighting and railroad properties that pay, are so constrained by business relations as not to be able to conduct college work; and college men, when summer comes, take refuge, as a rule, in the country rather than in a shop or factory, and so begin their autumn work with small additions to a usually scant fund of practical information. However, the electrical manufacturer and lighting and street railway manager are generally glad to assist the schools, as many who have received courtesies at their hands can testify; and if close relations between the school and practice do not obtain, it is the fault of the college man. In short, the college man should, during his so-called vacations, work as hard in collecting material for the coming season's lectures as he does during the scheduled period for conducting classes. The instructor in electrical engineering has, of course, the newness of his subject as a special difficulty to contend with; but if he follows the practice of visiting every year the plants of the manufacturing companies, typical lighting and power stations, etc., information is obtained which can not at present be found in engineering literature and which has the highest value for instructional purposes. When an instructor in technology is engaged it should be with the understanding that the cultivation of close relations between college work and outside practice is a part of his duty; and a limited consulting practice, when not conducted to the injury of the practicing engineer, should be encouraged.

I have adopted the following method in teaching dynamo design. First, the student is drilled in the theory of electro-magnetism and the magnetic circuit and is then required to fill out in detail the same data sheets that are used by our best manufacturing firms, for a number of machines of which working drawings are available. I find this especially useful in giving the student an idea of the proportions which obtain between the parts of single machines. Next, curves and tables are made showing the variations in the principal proportions of machines of different types and sizes. This gives the student an idea of the change in particular proportions with conditions of service and output. Necessarily the data possessed by a technical school are not of the latest; but by securing supplementary information each summer, a very close approximation to correct practice is obtained. Having worked over all the material available, the present tendencies in dynamo design are pointed out as well as may be, and explanations are given. Then a line of machines for certain assumed conditions is decided upon and each student takes one machine. The work after this is largely at the drawing board. The advantage of having all students working on machines of the same type but of different dimensions is, that by comparing notes they are able to see clearly the necessary change in dimensions, as the output, etc., of the machines vary.

A line of standard D. C. and A. C. machines are always required ; and special machines, if time allows. All drawings are made uniform, and complete data sheets are filled out for each machine. Next, the data and drawings are submitted for criticism to some one whose business it is to design machines to maintain reputation and earn income for those who invest their money in the manufacture of electrical machinery. In this way it is attempted to give the student salable information without sacrificing principles to unnecessary detail.

Lectures on electrical lighting, street railways, and general installation work are supplemented by a required design of a lighting or railway plant. A number of scale drawings of towns of various sizes are available, and from known or assumed conditions the station is located. Then, if it is a lighting plant, the locations of individual consumers are assumed, with particular load diagrams for each. From the individual load diagrams the nature of the station load is determined and the machinery and circuits are laid out. All circuits are calculated, and are shown on the map together with poles and important accessories. Setting plans for standard machinery are readily obtainable, and the station is arranged accordingly. This is, of course, the ordinary preliminary survey of the consulting engineer. Next, full specifications for the plant are drawn, definite as regards results to be obtained, but impartial as regards standard apparatus. Well-drawn sets of similar specifications are of course available to the student and are criticised for his benefit.

Lastly, a bill of material is made and costs are worked out for some one type of standard machinery, using price lists and labor estimates; and the cost of operation and maintenance, and the income necessary to make the plant a paying investment, are determined. Such station plans and estimates are then checked by a constructing engineer whose routine work keeps him directly in touch with such matters.

The tendency to carry system to an extreme in some engineering laboratories is greatly to the students' disadvantage. If, on entering a laboratory, a student is met with a long list of inconsequent experiments, handed a series of laboratory forms, and told to begin observations using apparatus already set up by a laboratory assistant, his interest in research takes rather a sudden fall. Having explained the use of instruments, the general methods of dynamo testing, and the peculiarities of particular machines, better results are obtained by turning over to a group of students a dynamo with necessary testing apparatus, and letting them work out results as far as possible unaided. Care must be taken, however, to point out the tests that have a commercial value.

After having equipped a dynamo laboratory with machines of standard type to furnish current in necessary quantity and at convenient voltage, I believe the remaining space should be filled with what in effect are simple testing blocks. Then as new machines come upon the market they can be borrowed tested, and returned, giving new apparatus for investigation, without finally making a junk shop of the laboratory.

I believe very thoroughly in the value of a thesis requirement for undergraduate technical work. It is not expected that such theses will develop new principles in engineering, as some seem to expect; but very much valuable data is obtained, as to the various types of new apparatus continually coming out and the student learns to assume responsibility by being in a large measure left to his own resources.

Another expedient of utmost importance in bringing schools of electrical engineering into close contact with current development, is that of having specialists in the several fields of practical work give courses of lectures detailing the status and probable development of their work. One lecture by a distinguished engineer, while it interests for an evening, does not meet the requirement. I find courses of about ten lectures to cover satisfactorily such special topics as the design and construction of power plants, electric measuring instruments, etc. On these courses of lectures the student should be examined as upon work given by the ordinary instructors. As long as instruction in electrical and other special branches of engineering cannot in general be preceded by longer courses of preliminary training, on account of the pressing demands for technical information made by the recent enormous growth of our industrial interests, the granting of a full engineering degree for the ordinary four years of college work seems unwarranted. The recent graduate is not an engineer; we only hope he has the capacity to become one. A safer course, and one which I have adopted in granting the degree of Electrical Engineer, is to require certain additional or graduate work after the bachelor's degree; and the full degree is conferred at any subsequent time when the applicant presents a dissertation showing that he has actually planned and carried out electrical work of some importance. If such a practice were general I believe the degree would secure more attention than it does at present. A continued effort should also be made to raise the entrance requirements to engineering courses. This will finally be effective, I think, in bringing the special branches of engineering into our graduate schools along with other strictly professional work.

AT WHAT POINT SHOULD STUDENTS ENGAGE IN SPECIFIC RESEARCH, AND HOW MUCH AID SHOULD BE GIVEN BY THE PROFESSOR?

BY CHARLES D. MARX,

Professor of Civil Engineering, Leland Stanford Junior University, Stanford University, Cal.

To answer the question outlined in the title of this paper, a title suggested by our Secretary, it becomes necessary to see if reason exists for a change of opinion expressed by the writer on this subject in 1893.

During the exposition year our technical schools and their methods of instruction were carefully studied by the leading engineers, manufacturers, and technical educators of other countries. The results of these investigations have been published and contain much food for thought. The writer has been especially impressed with the careful studies made by Professor Riedler, of Berlin, on the technical schools of America, and by Professor Martens, of the Royal Testing Laboratory, on American Testing Laboratories, including both appliances and methods of instruction. A reference to these papers and to the points raised in them is not amiss to the discussion of the question before us.

Professor Riedler holds that, outside of the instruction in the laboratories, instruction in American technical schools stands on a decidedly lower plane than in Austria or Germany. The reasons for this are two-fold : lack of preparatory training on part of the students, and lack of thoroughly trained teachers of engineering, *i. e.*, teachers who combine theoretical training with a wide and constantly widening practical experience.

It becomes evident at once, therefore, that if our students are to engage in a specific research, we must first overcome the criticised defects in their preparatory training. This, we all know, is a matter of considerable difficulty, and the recent work done by your committee on entrance requirements but emphasizes the fact. If a part of the present four-year curriculum must be devoted to the making up of deficiences in the student's general education, if the time must be given to studies in English, French, German, history and literature, there remains little enough time for the grounding of the student in the elements of his profession. That this grounding must take precedence over any attempted specific research, we probably all stand ready to admit. The natural conclusion then is: Specific research should not be undertaken in undergraduate courses. If we eliminate such work therefore from the undergraduate course, it becomes of importance for but a limited number of students. This, in the writer's mind, is no objection; it will probably lead to the doing of a small amount of careful work, rather than to the piling up of a large amount of undigested and indigestible data. Our economic conditions are such, that not many students can afford to spend a fifth year at college in post-graduate study, nor, in the opinion of the writer, is this desirable in most cases. Specific research undertaken by such fifth-year men must of necessity be undertaken largely under the professor's direction if it is to be of much value, and serious difficulties stand in the way of this. It would be much better if our young graduates could enter at once on the practice of their profession, and then return, *if possible* (and well the writer knows how seldom that would be), for the study and experimentation necessary for the solution of some particular problem. If a college is wealthy enough to provide working facilities for such men, no better paying expenditure for its funds can be found.

To return, however, to our fifth-year student. As stated, the material to be dealt with needs careful guiding and much help. Can the average American teacher of engineering, overburdened with teaching a multiplicity of subjects, do this guiding and give the help? He cannot. Is it not true that many vacancies in the teaching staffs of engineering colleges of large attendance, as well as in small colleges, are filled with recent graduates with but little practical experience? Are these young men, earnest and faithful though they may be, qualified to act as such guides? They are not. If then the conclusion, on the one hand, is that there should be directed specific research only in fifth-year courses, and, on the other, that the overburdening of the professor does not admit of his giving such direction, then it would seem that there is but little room for specific research in our technical schools as at present organized. It does not follow, however, that such research is not desirable. To make it profitable and valuable, two things must be done. The American professor of engineering, like his colleagues in other countries, and even to some extent in other lines of work in this country, must be relieved of work so that he can specialize along some line; and preferably he should be called from the practice of some particular line to teach that specialty. He should have ample leisure for carrying out original work, which, in our profession, is often synonymous with standing in actual practice. Such a man, directing the work of students, will see that it is not frittered away in useless gropings after the unattainable, and that general conclusions are not drawn on the basis of a few isolated experiments. Theory, practice, and economic factors will be given due weight in his teaching. But men of this stamp cannot be had for the salaries which boards of trustees, as a rule, are willing to pay to engineering teachers; nor are such boards, as a rule, willing or able to provide the necessary number of *professors,* not instructors, which specific research on the professors' or the students' part demands. The writer recognizes that the first duty of a professor of engineering is to his students. As a teacher, he should strive to provide for his students the best possible *instruction* in the form of *independent* work in laboratory, drafting room, and field. All equipment should be acquired with this end in view primarily. When all the demands along those lines are met, when the teaching corps and the available funds are ample, then, and then only, should provision be made for the research or original work of professors, and it goes without saying that the research work of the students must follow in the wake of this. These thoughts were expressed in a report made by the writer in '91 to President Chamberlin of the Wisconsin State University; and it gave the writer no little pleasure to find them echoed in a paper on American Testing Laboratories, by Professor Martens, of Berlin, published in the Z. d. V. D. I., 1895, page 981.

The criticisms of Riedler, Martens and others, on our technical schools, merely confirm the writer in his views expressed in '93, that no attempt at specific research should be made in undergraduate courses, but that our every endeavor should be to broaden the men and to give them a good grounding in the elements of the profession. Post-graduate research work is desirable if it can be undertaken under the direction of a professor thoroughly competent and with sufficient leisure to direct the work. Work of this character will generally call for the installation of separate laboratories with special equipment, so as not to interfere with the work of instruction; and it must, therefore, for some time to come, be restricted to a few of the largest and wealthiest technical schools. If, as before stated, graduate students return from actual practice for the study of special problems arising in practice and can work in such laboratories in conjunction with the professors who have leisure for research, then, in the opinion of the writer, the best possible conditions for research work will exist.

Discussion.

Professor Johnson said that, in his opinion, the conclusions reached were entirely correct.

President Eddy thought if no one held any opinion different from that, certainly there was no present occasion to discuss the subject.

A MEMBER remarked that the ideas advanced by the author are quite different from the common practice.

PRESIDENT EDDY replied that a good many instructors are certainly trying to do something in the way of research with their students.

UNIFORMITY OF SYMBOLS.

REPORT OF THE SPECIAL COMMITTEE.

To the Society for the Promotion of Engineering Education:

At the third annual meeting, held at Springfield, the committee was appointed to report a uniform system of symbols for engineering literature. At the fourth annual meeting a report of progress was submitted; but as only one member of the committee was then present, the committee was continued and requested to report in print thirty days before the next meeting. In pursuance of that vote of the Society, the following report is submitted:

Early in the history of the committee, by means of correspondence, a series of guiding principles was adopted, and each member of the committee was appointed to prepare a preliminary report upon a division of the general subject. These guiding principles and the reports of the sub-committees constitute this report. Each member of the committee regrets that it has been impossible to secure a meeting of the committee, and that, therefore, the several sub-reports have not had careful consideration by the other members of the committee.

GUIDING PRINCIPLES.

1. Eliminate, as nearly as possible, all Greek symbols from engineering text-books.

2. Restrict the significance of each letter or symbol to a single meaning in a single subject.

3. As far as possible, adhere to the symbols now commonly used in engineering text-books.

4. As far as possible, take Rankine's notation as a basis for symbols to be used in mechanics.

The reports of the members of the committee upon the special subjects assigned to them as sub-committees immediately follow.

IRA O. BAKER,
J. GALBRAITH,
D. C. JACKSON,
J. B. JOHNSON,
WM. KENT.

ELECTRICAL ENGINEERING SYMBOLS.

BY DUGALD C. JACKSON,

Professor of Electrical Engineering, University of Wisconsin, Madison.

The accompanying report on electrical symbols for text-books consists of four exhibits marked A, B, C, and D. These are respectively: (A) the international notation proposed by the distinguished Professor Hospitalier, which was revised and endorsed by an eminent committee of the last Electrical Congress (Chicago, 1893), but which was not authoritatively adopted by the Congress; (B) the remarks made on (A) by the Committee on Units and Standards of the American Institute of Electrical Engineers, in response to a communication which I sent to the Secretary of that society, inviting an expression of opinion as to the best notation relating to electrical and magnetic quantities, for use in text-books; (C) the action taken with regard to symbols by the Frankfort Electrical Congress; and finally (D) a table of symbols, which I have compiled, and which I present as my report on Symbols for Electrical Engineering.

In selecting symbols for the different engineering quantities, the following considerations appear to me to require careful attention by the committee, in order that the notation may be generally adopted, and that, when adopted, it may be of the greatest service to students, teachers, and the engineering profession of the country.

1. The notation should include only symbols repre-

senting physical quantities, units, or constants, which are in general use and are of importance in engineering branches, or which hold fundamental places in the development of such engineering quantities, units, or constants.

2. The symbols chosen should be such as have a reasonable chance of general adoption by American text-book writers and publishers of engineering or trade publications. With this in view, it is desirable to use only such styles of letters as are likely to be found amongst the type of first-class book printing establishments.

3. A universal system of symbols for use in American text-books should include, as far as may be, the special symbols which are already in common use in the best text-books and other publications in the English language. In other words, as little violence should be done to well established nomenclature in special subjects, as is consistent with making a satisfactory general system of notation.

4. Any symbol may be given various significations, but these should be so chosen that they cannot possibly conflict, and that the meaning in any particular use of the symbol shall be always evident from the context.

The importance of these considerations is so nearly self-evident that little need be said to support them, but the following suggestions may serve to show their importance more plainly. A generally adopted notation would be of little service if so extended that a chart must be consulted whenever the meaning of a symbol is desired. The symbols should belong to salient features which may be remembered by students, teachers, writers, or readers. An unduly extensive list of symbols is of doubtful use, since, even if remembered and used, it adds little to the clearness of any treatment. After the symbols for the salient features are adopted, those for the minor features may be safely given over to the individual treatment of authors, since the meaning of such minor symbols may often be seen at once from the context, or may be shown by proper subscripts. This applies especially to symbols used in papers and articles published in engineering transactions and periodicals; and if an adopted notation does not serve for these also, it loses much of its force as an engineering text-book notation, except for the text-books covering the fundamental subjects of pure and applied mathematics and mechanics, which are already far better in point of notation than are the more strictly engineering text-books. In the same way, if great violence should be done to such notation as is now generally adopted in our text and reference books, the result must be to cause greater confusion, since a great number of those books which are now in use will continue in use many years, and the addition of an independent set of symbols for use in new books would add another element to the present confusion.

In addition to the four considerations already named, the following two appear to me to be of importance (the fifth vitally so, but the sixth perhaps in a less degree than the others), but the principles which they assert are directly opposed by those who recommend the general adoption of Professor Hospitalier's notation.

5. In order that a new system of symbols may be

of the greatest service in this country, every effort should be made to make it generally satisfactory in America and England, in order that the largest possible number of engineering publications printed in the English language may adopt it quickly and use it exclusively. No sacrifice of this object is justified for the purpose of gaining further international adoption.

6. It is desirable that the symbols be neat in appearance and harmonious with ordinary type.

I shall not take space for argument upon the fifth and sixth considerations, but I wish to point out the fact that Hospitalier's notation violates both, since it sacrifices the possibility of gaining immediate and perhaps ultimate adoption by many American and English writers and publishers, on account of the unusual and unæsthetic form of many of its symbols, which are in special script. It is now more than four years since that notation was brought before the Chicago Electrical Congress, and even longer since it was first published by its author in its original form, but it has been little used in new books printed in English, and still less in transactions and periodicals. Nearly all important elementary or advanced books relating to electrical science, which have been printed in English since 1893, have used an entirely different notation.

The Hospitalier notation admirably fulfils the requirements of the first and fourth considerations, but it is violently in opposition to the second, for the same reason that it is in opposition to the fifth. It also fails to fulfil the third consideration, since it replaces several commonly used Roman symbols by script symbols; and it comes into distinct conflict with this consideration by using I, i as the symbol for electric current instead of C, c, which is commonly used in English print. In English print it is customary to use I to represent intensity of magnetization, but in the Hospitalier notation this quantity is represented by $\mathscr{I}$.

I have occupied so much space in discussing the international notation proposed by Professor Hospitalier and revised by the Chicago Congress Committee, because of the remarkably strong endorsements which it has received in the past and of the approval which is given to it in the annexed exhibit B; but it fails in so many points to fulfil the requirements of an American text-book notation that it does not seem that this committee is justified in presenting it to the Society for the Promotion of Engineering Education with a view to its adoption thereby. Such an adoption would, doubtless, be barren of results, as have been the strong endorsements that the notation has already received. This, unfortunately, being the status of the Hospitalier notation, I have rather reluctantly undertaken to compile a new notation covering the special electrical and magnetic quantities, which is presented herewith as Exhibit D. This notation is in exact conformity with the requirements of the first, second, fourth, fifth, and sixth considerations, and fulfils the requirements of the third as completely as can be done by choosing symbols which are used in the largest number of existing publications, and which fulfil the requirements of the other considerations. The only deviation which I have made from the most generally accepted symbol, is in the case of electrical capacity, which is usually represented either by C, c or by K, k. In treating alternating current phenomena the symbols for current and capacity may enter the same equations; it is desirable to retain C, c in its almost universal use (in the English language) for current, and the letter K, k is already overburdened by its duties as a constant in addition to various special significations. I have, therefore, chosen the letter S, s to represent electrostatic capacity. No well-defined custom has grown up in the use of symbols representing reluctance and reactance. For the former, Professor S. P. Thompson uses Z, but I have chosen P as being more in harmony with the use of R for resistance. For reactance, I suggest a choice between two symbols, ℞ and J. The first seems preferable, as the only objection which can be urged against it is its traditional connection with the physician's prescription. It is a commonly found symbol and is easily indicated in manuscript. For impedance, I have chosen I, which is now so used by several excellent authorities. Since great variety exists in the use of symbols for frequency, I have chosen an entirely new one, f, which seems particularly applicable. The most common symbol for frequency is probably n, but this letter is already overburdened with various text-book duties, and it is very convenient for use in electrical text-books with the signification of the number of turns of wire in a coil. Some writers use it both for turns and for frequency. In many cases, where no confusion can be caused thereby, I have indicated a choice of forms for the same letter, the choice being between Italic and bold face capitals, as H or $\mathbf{H}$. While I prefer the Italic form on account of its more symmetrical appearance in a page of print, both forms have the sanction of good usage. In the case of electric current, I have indicated a choice between the symbols C and I, giving preference to the former because of its far more general use. The I is particularly undesirable here because it is also used for impedance; and since current and impedance are likely to enter the same equations, it would possibly be better to suppress this option.

The notation which I here present, if approved by the whole committee and adopted by the Society, appears to have every qualification necessary to bring about its immediate and general adoption in English print. Its various elements have the sanction of usage in such journals as the *Electrical World*, *Electrical Engineer*, *London Electrician*, etc., and in the late writings of such eminent authorities as Mr. Steinmetz, Professor Ryan, Professor Ewing, Professor J. J. Thomson, Dr. Hopkinson, Professor S. P. Thompson, and many others, both in this country and in England. The only effective criticism which can be brought against this notation is that it is based upon our proven requirements and best usage instead of upon some scientific or logical and universal plan. Such a criticism, however, is scarcely valid, especially after the comparative neglect in English print of the beautifully devised scheme of Hospitalier and the Chicago Congress Committee.

EXHIBIT A.

Hospitalier's Notation.

As revised by a Committee at the Chicago Electrical Congress.

Endorsed by the Units Committee of the American Institute of Electrical Engineers.

Length,	L, l.	Angle,	α, β.	Energy or work,	W.
Mass,	M.	Velocity,	v.	Power,	P.
Time,	T, t.	Angular Velocity,	ω.	Pressure,	p.
Area,	S, s.	Acceleration,	a.	Moment of Inertia,	K.
Volume,	V.	Force,	F, f.		

Strength of magnet pole,	m.	Magnetic induction,	$\mathcal{B}$.
Magnetic moment,	$\mathcal{M}$.	Permeability,	μ.
Intensity of magnetization,	$\mathcal{I}$.	Susceptibility,	κ.
Strength of field,	$\mathcal{H}$.	Reluctivity,	ν.
Flux of magnetic force,	Φ.	Reluctance,	$\mathcal{R}$.

Resistance,	R, r.	Electrical energy,	W.
Conductance,	G, g.	Power,	P.
Electro-motive force,	E, e.	Resistivity,	ρ.
Difference of potential,	U, u.	Conductivity,	γ.
Current,	I, i.	Coefficient of inductance,	L, l.
Quantity,	Q, q.	Magnetizing force,	$\mathcal{H}$.
Capacity,	C, c.	Magneto-motive force,	$\mathcal{F}$.

EXHIBIT B.

American Institute of Electrical Engineers, Havemeyer Building, N. Y., Feb. 15, 1896.

PROF. D. C. JACKSON, UNIVERSITY OF WISCONSIN, MADISON, WIS.

Dear Sir: The Council of the American Institute of Electrical Engineers, having considered your communication of the 8th of January, has referred the same to its "Committee on Units and Standards." The Committee has carefully considered your communication and strongly recommends the system of notation and symbols which was prepared by the Committee on Notation of the Chicago Electrical Congress, and which is printed as an appendix to its proceedings. This system of notation has already been widely adopted in this country and has received very favorable support in Europe, although it has not yet received very favorable report in Great Britain, where, however, no definite system of notation seems to have been decided upon, and, consequently, so far as we know, no definite alternative system is offered by British text-books or technical journals.

The only objection found by our Committee in the notations and symbols of the Chicago proceedings is the introduction of the symbol I for current strength, but we do not see how this difficulty can be avoided without practically introducing complete dissension with European practice and the whole scheme of notation, so that we believe it better to sacrifice some convenience on this score for the benefit of an approach to international notation.

Since this table was prepared by the Committee of the Chicago Electrical Congress, several new terms have come into use, as you are aware, in connection with alternating current circuits, and the following symbols have been suggested in correspondence with M. Hospitalier, pending any official action upon the notation of these quantities:

Impedance,	Z, z.	Reactance,	X, x.
Admittance,	Y, y.	Susceptance,	B, b.

It is found convenient in dealing with alternating current phenomena to employ, by special stipulation, the capitals for vector quantities, and small letters for scalar quantities. Unless such stipulation is made, however, no distinction is understood.

The American Institute of Electrical Engineers is in favor of the use of the terms gilbert, weber, gauss and oersted for the C.G.S. units of M.M.F., magnetic flux, flux density and reluctance.

A complete table of the notation has been reprinted from the Chicago Congress Proceedings by the *Electrical World*, and you are no doubt familiar with this reprint. Yours respectfully,

A. E. Kennelly,
For the Committee.

Exhibit C.

Action of the Frankfort Electrical Congress in 1891.

"Symbols representing physical quantities to be taken in Italics. Symbols of units to be in Roman type, and symbols of physical constants and angles to to be taken in Greek type."

[This action of the Frankfort Congress, and the action of a committee of the formal Chamber of Delegates at the Chicago Congress (1893) in endorsing the revised Hospitalier notation, are the important acts in relation to the adoption of a fixed notation which have been made in authoritative Electrical Congresses. It is to be particularly noted, however, that the Chamber of Delegates at Chicago refused to adopt the recommendation of its committee, but disposed of its recommendation by passing a motion that the report be received as the work of the committee dealing with the subject, and that it be printed as an appendix to the proceedings of the Chamber. The revised notation (Hospitalier's) referred to here is given in Exhibit A, and is the same as that urged for adoption by the Committee on Units, of the American Institute of Electrical Engineers, whose position is outlined by the report given in Exhibit B. *D. C. J.*]

Exhibit D.

Recommendation of the Sub-committee on Electrical Symbols, of the Society for the Promotion of Engineering Education.

Magnetizing force and strength of field,	H or $\mathbf{H}$.	
Number of lines of force, magnetic flux,	N or $\mathbf{N}$.	
Induction, magnetic density,	B or $\mathbf{B}$.	
Reluctance, magnetic resistance,	P.	
Magneto-motive force, magnetic pressure,	$\underline{M}$ or $\mathbf{M}$.	
Ampere turns,	$\overline{nc}$.	
Permeability,	μ.	
Current (electric),	C, c or I, i	This use of I, i for current is allowable only in formulas relating to continuous currents or in alternating current formulas into which impedance does not enter. The option might possibly be suppressed with advantage.
Resistance,	R, r.	
Reactance,	℞ or J.	
Impedance,	I.	
Electro-motive force, electric pressure,	E, e.	
Quantity of electricity,	Q, q.	
Electrical capacity,	S, s.	
Electrical potential,	V, v.	
Self-inductance,	L.	

Mutual inductance,	M.
Frequency of an alternating current,	f.
Angle of lag in an alternating current circuit,	φ.
Commercial efficiency,	η.

Subsidiary quantities.

Strength of pole,	m.
Intensity of magnetization,	I.
Magnetic susceptibility,	k.
Solid angle,	w.
Angular velocity,	ω.
Revolutions per minute,	V.
Number of turns in a coil,	n.

MECHANICAL ENGINEERING SYMBOLS.

BY WM. KENT, M. E.,

New York City.

Abscissa, x.

Acceleration (= increase of velocity ÷ time), a.

Acceleration due to gravity, g.

Angles A, B, C, D, E; α, β, γ, δ, θ, φ, ω.

Angle of bend in a pipe, i.

Angular velocity, A, a, α, ω.

Angular movement, ω.

Arc of contact (belt on pulley), θ (in ratio of length of arc to radius).

Areas, A, a, S, s.

Arm of a lever, or of a moment, A, a, L, l.

Axis of abscissas, X; of ordinates, Y.

Base of Naperian logarithms, e, $= 2.7182818$.

Breadth or width, B, b, ft. and ins., or greater and smaller; B_1 B_2, b_1 b_2, different breadths.

Capacity (pumps, pipes, etc.), G, gallons per min.; Q, cubic ft. per min. or per sec.

Centigrade, C.

Centigrade-gramme-second system, $C.$ $G.$ $S.$ system.

Clearance, c, in parts of stroke.

Coefficients or constants, A, B, C; a, b, c; K, k, f, e, E, G, n.

Coefficients of elasticity: E, in tension, compression, or bending; G, in torsion or shearing.

Coefficients of conductivity for heat, K, k.

Coefficient of expansion by heat, e.

Coefficient of efflux from an orifice, k.

Coefficient of flow in tubes, c.

Coefficients of friction, f, k (in ventilation of mines).

Coefficient, fractional, n.
Coefficient of roughness, in Kutter's formula, n.
Constants, A, B, C, K, A_1 A_2, etc. (same as coefficients).
Compressive strength or stress, C.
Deflection, D, Δ.
Deformation, D, β, λ, γ.
Density, d, δ, s (specific gravity).
Depth, D, d (ft. and ins., or greater and smaller);
D_1 D_2, d_1 d_2, different depths. (Some writers use h for depth, thickness, etc. In formulas for beams, and even for diameters, d is preferred, as being the initial of the word, and because h is used for many other things.)
Diameter, D, d, (ft. and in., or greater and smaller);
D_1 D_2, d_1 d_2, different diameters.
Difference, d, Δ, p (difference of pressure or $p_1 - p_2$).
Differential, d.
Distance, known, a, b, etc.; a_1 a_2, etc.;
variable, x, y, z, etc.
Distance of neutral axis from extreme fibre, y.
Efficiency, E.
Elasticity, modulus of,
in tension, compression and transverse stress, E;
in torsion and shearing, G.
Elongation λ (per unit of length $\frac{\lambda}{l}$).
Energy, U.
Exponents, m, n.
Factor of safety, f. (When a factor of safety, f, is used in a formula, the force, pressure, stress, or load, should be represented by some other letter.)
Fahrenheit, F.
Force, F, total; f, per unit of area.
P, W, pressure or load, total; p, w, per unit of area.
S, s, stress; C, c, force acting in compression;
T, t, in tension; R, r, resistance.

H, *h*, head of water, air or gas.

Capitals for total forces, small letters for forces per sq. in. or other unit of area.

Function, *f*. (The use of this letter to mean "function of" should always be explained in the context).

Friction, coefficient of, *f*. (*k* in ventilation of mines.)

Gallons, *G*.

Gauges, *A. W. G.* or *B. & S.*, American, or Brown & Sharpe.

B. W. G., Birmingham.

S. W. G., standard British.

U. S. G., standard U. S. of 1893 for plates and sheets only.

C. M. G., circular mil gauge.

M gauge, gauge reading in thousandths of an inch.

Gravity, acceleration of, g.

Gravity, specific, s, ϑ.

Head, H, h, ft. and in., or greater and less.

Heat, total in heat units, H, h, greater and less.

H_1 H_2, h_1 h_2, different values.

Heat, latent, L.

Heat, specific, C; of gases at constant volume, C_v; at constant pressure, C_p; ratio of specific heats, $C_p \div C_v = k$.

Heat, coefficient of thermal resistance, K, e.

Heat, mechanical equivalent of, J (reciprocal of do., A).

Height, H, h (ft. and ins., or greater and less);

H_1 H_2, h_1 h_2, different heights.

Heaviness, weight per cubic foot, w.

High pressure (cylinders), *h. p.*

Horse-power, *H P*.

Horse-power, indicated, *I. H P*.

Horse-power, brake, *B. H P*.

Horse-power, electrical, *E. H P*.

Hydraulic coefficient (flow of water in pipes), c. Chezy's formula, $v = c\sqrt{rs}$. (r = mean hydraulic radius, s = slope.)

Integral, $\int$.

Intermediate pressure (cylinder), *i. p.* (first and second intermediate, *1st int.*, *2d int.*).

Joule's equivalent, J. (Reciprocal of $J=A$.)

Latent heat, L.

Length, L, l, ft. and ins., or greater and smaller ; L_1 L_2, l_1 l_2, different lengths.

Lines, a, b, c, etc.

Load, live, P ; per unit of length or area, p.

Load, dead, W ; per unit of length or area, w.

Logarithm, *log.* (common) ; *Nap. log.* or *hyp. log.* (Naperian or hyperbolic). (*log*, *l*, or log_e should not be used for *Nap. log.* unless the notation is explained in the context.)

Low pressure, *l. p.*

Mass, m ($= \frac{W}{g}$ $W=$ weight, $g=$ acceleration due to gravity at the place where the weight is measured; the weight being that which would be shown by a spring balance standardized at London. If the weight taken is that which would be obtained by counterpoising on an even balance scale, then the value g at London is to be used, viz. 32.19.)

Mechanical equivalent of heat, J.

Modulus of elasticity, E (G for torsion or shearing).

Modulus of resilience, R_s, do. at elastic limit, R_e.

Modulus of rupture, R.

Moment, M, M_1 M_2, etc.

Moment, bending, B ; twisting, T.

Moment of inertia, I. (Polar moment of inertia, J.)

Number, N, N_1 N_2, n, n_1 n_2.

Number of single strokes per minute, N.

Number of revolutions, or double strokes, per minute, R, *rpm.*

Number of revolutions per second, *rps.*

Ordinate, y.

Orifice, area of, o, a.

Origin of moments or pole, O.

Perimeter of channel (ventilation), O.

Pitch, of teeth, rivets, screw threads, etc., p.

Points, A, B, C, P, Q, R, etc.

Polar moment of inertia, J.

Progression, arithmetical and geometrical, a=1st term, l=last term, n=no. of terms, m=any term, s=sum of terms, d=constant difference, r=ratio or multiplier.

Pressure or load, P, total; p, per unit of area.

P_0, P_1, P_2, p_0, p_1, p_2, different pressures.

P_0, p_0, pressure at zero temperature.

$M. E. P.$ mean effective, (or p when so explained).

Quantity, cubic ft. per second, Q; per minute, Q'.

Radius, R, r, ft. and in., or greater and smaller.

R_1, R_2, r_1, r_2, different radii.

of gyration, R, least, do., r.

of curvature, r, ρ.

mean hydraulic, r, $= \dfrac{\textit{area of wet cross section.}}{\textit{wet perimeter.}}$

Rate of volume discharge=volume÷time, q.

Ratio, R, r, R_1, R_2, r_1, r_2, etc.

of circumference of circle to diameter, π, $=3.1415926$.

of expansion, R, r, etc.

Resistance, R; do., per unit of area, r.

Resilience, total, R_t; per unit of volume, R_e (modulus of resilience).

Sectional area, A, a.

Section modulus, $Z = \dfrac{I}{y}$

$$= \frac{\textit{moment of inertia.}}{\textit{dist. of neutral axis from extreme fibre.}}$$

Shear, S.

Shearing elasticity, modulus of, G.

Slope = head ÷ horizontal length = tangent of angle of inclination, S.

Speed, V, v, K (knots per hour).

Specific gravity, s, δ.

Specific heat, C; at constant volume, C_v; at constant pressure, C_p.

Stress, S; per unit of area, s; per sq. in. at extreme fibre, s; tension, T, t; compression, C, c; shearing, S_s.

Stroke, in feet, S.

Sum, s.

Summation, sign of, Σ.

Surface, area of, A, a, S, s.

Temperature, Fahr. or Cent., T, t, greater and less.

T_0, t_0, zero temperature.

T_1, t_1, T_2, t_2, different temperatures.

T_0, T_1, T_2, absolute temperatures. F, Fahrenheit; C Centigrade.

(When Centigrade scale is used, the letter C should always be given with the temperature. When no letter is given, Fahrenheit is understood.)

Tensile stress, T; per unit of area, t.

Tension, T, T_1, T_2 (tension of a belt).

Thickness, t, t_1, t_2.

Time, t, t_1, t_2.

Torsional elasticity, modulus of, G.

Velocity, V, V_0, V_1, V_2, v, v_0, v_1, v_2; u, u_1.

generally, v, ft. per sec.; V, ft. per min. or miles per hour.

Volume, V, total: v, per unit weight.

V_0, v_0, volumes at 0° temperature; V_1, V_2, v_1, v_2, other volumes.

Weight, W, w, greater and less; per unit area or length, w; W_1 W_2, w_1, w_2, different weights.

Work, W, U.

Note on Greek Letters.—Greek letters should not be used when Roman letters will answer the purpose. Angles may usually be as well expressed by Roman capitals as by Greek letters. The increasing use of type-setting machines is an objection to the use of Greek letters. The use of π, however, is universal, and this character should be included in cases of Roman type, along with such symbols as $, %, etc.

Note on Subscripts.—Subscripts should generally be figures, as R_1, R_2, p_0, V_0, etc. Primes, seconds, etc., as R', R'', should be avoided. Letters may be used as subscripts when necessary to express quantities similar in kind, but different in time or location, as p_m, mean pressure, p_b, boiler pressure, p_i, initial pressure.

Subscripts should be avoided wherever practicable, and double subscripts, as f_{rc} are especially objectionable. They are difficult of comprehension by most readers; writers who use them have no uniformity in their use; they are liable to frequent errors in copying and proof-reading; they cannot be reproduced by the typewriter, or by type-setting machines; they mar the appearance of the printed page; and they give great trouble to printers and proof-readers, with consequent increase of cost of printing.

Comments of Mr. Kent upon the Reports of other Members of the Committee.

I approve of the following in Professor Galbraith's Report: "It seems impossible to invent a system wherein each quantity should have one symbol and each symbol one meaning, without causing an intolerable tax on the memory and defeating the whole object of any system of notation, viz., suggestiveness and legibility. The principle of taking the context into consideration largely reduces the number of necessary symbols."

"No system of notation or nomenclature should be pushed too far. Minor inconsistencies in the use of symbols may lead to neater and more expressive formulas than if the system were rigorously adhered to."

Paragraphs numbered 1, 2, 3, 4, 5, and 6 in Professor Jackson's Report have my hearty approval.

In Professor Johnson's report, I approve his use of "deformation" instead of "strain," and I commend the action of Professor Johnson and of Professor Merriman in omitting the word "strain" from their most recent publications. I should like to see the word "strain" as a synonym for extension, compression, deflection, or other distortion or deformation, expunged from engineering literature, and if the word is to be used at all, it should be used in its ordinary sense in the English language, as synonymous with "pull" or "push," or with resistance of a bar, rope, etc., to an applied force.

I approve of Professor Galbraith's criticism of the terms "unit stress," "unit deformation," etc.; but do not approve of his proposed restriction of "stress" to mean "stress per unit of area." His new definition of "strain" only adds to the existing confusion as to the meaning of this word. I cannot approve of Professor Galbraith's proposals concerning "mass" and "weight" in the division C of his report, although some of his arguments are well taken. If the committee should endeavor to restrain the use of "weight," it would only add to the existing confusion in the literature of engineering. The use of the word "mass" instead of the popular word "weight," would not remedy the confusion, for the word "mass" itself has several meanings. Thus: 1. It is commonly used as synonymous with "bulk." 2. It is used as a mathematical expression for the quotient of weight divided by the acceleration of gravity, or $W \div g, = W \div 32.19$ (at London). 3. It is used to express (in scientific language) the quantity of matter in a body as compared with that in the standard pound at London; for example, a mass of 10 lbs. is one that would weigh 10 lbs. at London, on a spring balance which was standardized at London, or $10 \times \frac{32.16}{32.19} = \frac{10}{1.00093}$ lbs. at 40° latitude, or which would "weigh" 10 lbs. anywhere, if weighed on an even balance scale against a 10 lb. weight which had been standardized in London.

Professor Galbraith would restrict "weight" to mean the force of gravitation acting on the body. This is not its meaning in common language; for a weight of 10 lbs. is not understood as the force of gravitation which acts on a standard ten-pound weight in the United States (which force is $10 \times \frac{32.16}{32.19}$ lbs. at 40° latitude, as measured on a spring balance standardized at London), but as the quantity of substance which would counterpoise anywhere, on an even balance scale, 10 standard London pounds.

I think that this question of mass *versus* weight should be left for the mathematical physicists to wrestle with; and that engineers may well be satisfied, for the present at least, to use the word "weight" in its ancient and popular signification.

I propose the following for consideration by the Committee:

In papers furnished to engineering societies or to the technical press, if formulas are used only occasionally, the meaning of the symbols should in each case be given immediately below the formula. In such papers, if many formulas are used, the complete notation used should be given, either at the beginning of the paper or immediately following the introductory paragraphs. In a text-book relating to a single limited subject—for example, turbines—the complete notation should be given in the introductory chapter. In a text-book relating to more than one subject, the notation used in any chapter should be given near the beginning of that chapter.

The object of these directions is to save trouble to those who have occasion to use the papers and books as works of reference. In some recent books, the reader has to search through half the book in order to find the meaning of a particular symbol. In all cases, the author should consider that some of his readers may not be as familiar as himself with the meaning of the symbols he uses; and he should give the meaning of each symbol in clear terms, and in such easily found places in the book, that the reader may have no difficulty in finding it or in understanding it.

SYMBOLS FOR STATICS, DYNAMICS, STRENGTH AND ELASTICITY OF MATERIALS, HYDRAULICS, AND THERMODYNAMICS.

BY PROFESSOR J. GALBRAITH,

Professor of Engineering, School of Practical Science, Toronto.

The conclusions in the following report are based principally on Rankine's usage. The writer's method of procedure was as follows: All the symbols used in Rankine's "Applied Mechanics" and "Steam Engine" were classified under the heads in division (A) below. The study of these symbols indicated certain general tendencies which are made the basis of the system advocated in this paper. As far as possible, letters used by Rankine which seem inconsistent with his general scheme or tendency have been omitted or replaced by others. The greatest alterations have been made in thermodynamics. It would be well if writers in this subject could decide to use only one class of energy units, viz., mechanical units. The formulas present a much more simple appearance than when the double system of mechanical and heat units is used. It seems impossible to invent a system wherein each quantity should have one symbol and each symbol one meaning, without causing an intolerable tax on the memory and defeating the whole object of any system of notation, viz., suggestiveness and legibility. The principle of taking the context into consideration largely reduces the number of necessary symbols. There is hardly a word in an English sentence which has a definite meaning when standing alone. The words derive their meaning from the sentence, quite as much as the sentence depends for its meaning upon the words. If this were not the case it would be necessary to increase the number of words in use from five to ten fold in order to render language intelligible. What is true of words is also true of algebraic symbols.

Again, no system of notation or nomenclature should be pushed too far. Minor inconsistencies in the use of symbols may lead to neater and more expressive formulas than if the system were rigorously adhered to. Human nature rebels against formalism carried to extremes.

The symbols recommended are English capitals, English small letters, and Greek small letters, according to the following scheme:

A.

English Capitals.—Points, areas, volumes; angles, in degrees; forces and moments; moments and products of inertia; coefficients of elasticity; energy, work, momentum, impulse, power; temperature, in ordinary scales; heat, expressed in mechanical units; entropy and specific heats, in mechanical units per degree; Joule's equivalent.

English lower-case letters.—Lines, masses, time; all ratios, specific quantities and numbers, except when otherwise specified; hydraulic coefficients; absolute temperatures, in Thomson's scale; heat, expressed in heat units; entropy and specific heats, in heat units per degree.

Greek lower-case letters.—Angles, in radians; angular velocities and accelerations, in radians and seconds; density and its inverse; specific weight and its inverse; strains; coefficients of friction (solids); absolute temperatures, in scale of air thermometer.

It has been suggested that Greek letters should be abandoned. The writer does not concur with this view. Greek letters are easily made with the pen and are legible—good qualities not possessed by every alphabet.

The following are the principal symbols proposed under the above classification:

Points, A, B, C, etc.; P, Q, R, etc.
Lines, a, b, c, d; h, k; l, m, n; p, q, r; s, t; x, y, z.
Areas, A, S.
Volumes, V.
Angles, A, B, C, D; α, β, γ, δ; θ, φ, ϕ; π.
Forces, A, B, C, D; F, G, H; P, Q, R; S, T; W; X, Y, Z.
Moments, L, M, N.
Masses, m.
Velocities, u, v, w; angular velocity, ω, (radians and seconds).
Accelerations, f, g; angular acceleration, α, (radians and seconds).
Time, t.

Force per unit area $\left(\frac{P}{A}\right)$ p, (stress, see C, below).

Resistance per unit area, $\left(\frac{F}{A}\right)$, f, (stress, see C, below).

Weight per unit volume, $\left(\frac{W}{V}\right)$, w.

Volume per unit weight, $\left(\frac{V}{W}\right)$, v.

Mass per unit volume, $\left(\frac{m}{V}\right)$, ρ, (density).

Volume per unit mass, $\left(\frac{V}{m}\right)$, σ.

Moments of inertia, I, J, $\left\{\begin{array}{l}\text{in two}\\ \text{dimensions.}\end{array}\right.$ A, B, C $\left\{\begin{array}{l}\text{in three}\\ \text{dimensions.}\end{array}\right.$
Products of inertia, K, D, E, F,

Strains and distortions, α, β, γ,; λ, μ, ν, (see C, below).

Coefficients of Elasticity in Isotropic Bodies.

Coefficient of direct elasticity, A.
Coefficient of lateral elasticity, B.
Coefficient of shearing elasticity, C.
Coefficient of cubic elasticity, D.
Young's modulus, E.

Rate of volume discharge, $\left(\frac{V}{t}\right)$, q.

Hydraulic coefficients, c, f.

Sine of inclination to horizon, s.

Temperature.

Ordinary scales, T.
Absolute (Thomson's scale), t.
Absolute (air thermometer), τ.

Mechanical work, W.

Molecular potential energy, J.

Intrinsic energy, U.

Heat, Q, H, in mechanical units; q, h, in heat units.

Heat of vaporization, R, in mechanical units; r, in heat units.

Heat of the liquid, L, in mechanical units; l, in heat units.

Total heat of saturation, S, in mechanical units; s, in heat units.

Specific heat, C, in mechanical units; c, in heat units.

Ratio of specific heats of gases, $\left(\frac{C_p}{C_v} \text{ or } \frac{c_p}{c_v}\right)$, k.

B.

Besides the above, there are a limited number of coefficients and constants which it is hardly worth while to reduce to rule. When the choice of symbols is allowed, a good principle to observe is to select, when possible, the initial letter of the word intended. Subscript letters and numbers are to be used when necessary, and also letters marked with primes, seconds, etc.

The letters proposed above harmonize fairly well with those used in pure mathematics, in which the notation is comparatively well settled. While the above symbols are not in every case consistent with the general rules under *A*, yet the number of inconsistencies is, it is believed, much less than in Rankine's works.

C.

In connection with this subject, the writer takes the opportunity of making some suggestions with respect to the use of the words "weight" and "stress" and related expressions, with regard to which there is a good deal of uncertainty and obscurity in engineering and scientific treatises.

It would be well never to use the word "weight" when the "mass" of the body in question is intended, but to restrict its application solely to the force of gravitation acting on the body. An objection to this convention might be found in the fact that the statutes describing standards of mass, term them "weights." On the other hand, we have already a short word which means "mass," and that is the word "mass" itself; while we have no convenient word indicating the force of gravity, unless we use the word "weight." The word "gravity" does not seem suitable.

Again, it might be agreed to write 1 lb. when the pound unit of mass is intended, and 1 pd. when the pound force is meant. Unfortunately, we cannot distinguish very well by different contractions between 1 ounce or 1 ton (mass) and 1 ounce or 1 ton force (weight).

By the ounce, pound, or ton force, we mean, of course, the attraction of gravitation on the ounce, pound, or ton mass; and as this attraction varies with place, we have those very awkward things, variable units of force. The government takes care of the masses, or at least is supposed to do so, while the forces are left to take care of themselves.

Would it not be well to fix the force unit derived as above, by agreeing upon a standard place, say latitude 45° at sea level? No international jealousies need be stirred up by this location.

Other troublesome words are "stress" and its relative, "strain." Rankine generally uses the word "stress" to indicate a force continuously distributed over an area. When he is speaking of the amount of this force per unit area he uses the expression "intensity of stress." It has become the fashion in many modern books to call this quantity the "unit stress." Rankine's expression may be clumsy, but the modern innovation is barbarous. When we speak of a unit length, a unit area, a unit time, we mean such things as a foot, a square mile, a minute. The logical meaning of the expression "unit stress" is a unit force distributed over any area. It ought not to mean any force distributed over a unit area. It would be just as sensible to call in hydraulics the discharge per unit of cross-section "unit discharge;" or in electricity, induction per unit area "unit induction."

In some books, "unit stress" has brought with it "unit strain," meaning deformation per unit length, instead of unit deformation per any length, which is its natural meaning.

It is proposed that the words "stress" and "strain" be used no longer in their present sense as distributed force and deformation, but that they be used to denote what are now so absurdly called "unit stress" and "unit strain."

We should then speak of a stress of 3,000 pds. per sq. in., and of a strain of $\frac{1}{1000}$ in. per in., just as we speak of a velocity of 20 miles per hour, or of a density of 60 lbs. (not pds.) per cubic foot.

Hooke's law would then assert that the strain is proportional to the stress, instead of the unit strain to the unit stress.

If the present tendency continues, we shall have in a short time such monstrosities as "unit current is proportional to unit voltage," "unit force is proportional to unit acceleration," etc.

SYMBOLS FOR STRENGTH OF MATERIALS, FRAMED STRUCTURES, MASONRY, AND SURVEYING.

BY J. B. JOHNSON,

Professor of Civil Engineering, Washington University, St. Louis, Mo.

STRENGTH OF MATERIALS.

Modulus of elasticity, E.
Moment, M.
Bending Moment of Resistance, M_o; Moment of Torsion, M_t.
Moment arm, m or a.
Moment of inertia, I.
Moment of Inertia, J (polar).
Modulus of rupture, f_r.
Modulus of resilience, R_s.
Radius of gyration, r_g.
Radius of curvature, ρ.
Force of pressure (total), P.
Force of pressure (unit), p.
Centrifugal force, P_c.
Resultant, P_r.
Reaction, R.
Acceleration of Gravity, g.
Weight or load, w.
Stress (total), F_t, F_c, F_s, F_d, F_u.
Stress (unit area), f_t, f_c, f_s, f_d, f_u.
Deformation (total), $\triangle l$.
Deformation (unit length), λ.
Deflection, $\triangle$.
Percentage of Elongation due to temperature, λ_t.
Coefficient of expansion for temperature, ϵ.

Temperature (degrees), t.
Distance from neutral axis to extreme fibre, y_1.
Angular velocity, ω.
Angular deformation, a (in torsion).
Shear (vertical), S_v.
Area (total), A.
Area (unit), a.
Length (total), L.
Length measured, l.
Height or depth, and head, h.
Breadth or thickness or width, b.
Diameter, d.
Radius, r.
Coefficient of friction, C_f.
Velocity, v.
Angles, a, β, γ, θ, φ.
Distance, known, a_1, a_2, etc., b_1, b_2, etc.
Distance, variable, x_1 x_2, etc., z_1 z_2, etc.
Time, t.
Origin of moments or pole, O.
Number, N_1, N_2, etc.
Constants, k_1, k_2, etc., c_1, c_2, etc.
Exponents, m, n, etc.
"Section modulus," or modulus of section, $\frac{I}{y_1}$

Also , x, y, sin, cos, tan, sec, cosec, °, ′, ″, ft, in, etc.

FRAMED STRUCTURES.

Those given under Strength of Materials are not repeated here.

Length of span, l_s.
Panel length, l_p.
Number of panels, n.
Camber, c.

Horizontal force, P_x.
Vertical force, P_y.
Load applied at its center of gravity, G.
Dead load, total, W.
Dead load, unit area or unit length, w.
Live load, total, P.
Live load, unit, p.
Wind pressure, total, P_w.
Wind pressure, unit area, p_w.

MASONRY.

Weight (load), w.
Horizontal force or load, P_h.
Vertical force or load, P_v.
Force of gravity, g.
Pressure, general, P.
Pressure, horizontal, P_h.
Pressure, compression, P_c.
Pressure, normal or radial, P_r.
Pressure, resultant thrust, R.
Moment, M.
Moment of inertia, I.
Modulus of rupture, f.
Modulus of elasticity, E.
Area, A.
Rise (of arch), S.
Span, l.
Length, l.
Height or depth, h.
Breadth or thickness, b.
Distance, d.
Distance, perpendicular, a.
Velocity, v.
Batter (inclination), i.
Angle of repose, φ.

Coefficient of friction, $C_f = \tan \varphi$.
Radius of curvature, ρ.
Angles, $\alpha, \beta, \gamma, \theta, \varphi$.
Also x, y, etc.

SURVEYING.

Latitude, L.
Longitude, M.
Azimuth, Z.
Departure, D.
Double meridian distance, $D\ M\ D$.
Area, A.
Right ascension, α.
Declination, δ.
Polar distance, d.
Zenith distance, z.
Hour Angle, H.
Time, t.
Altitude, a.
Refraction, Q.
Coefficient of refraction, q
Coefficient of expansion, e.
Temperature, t.
Density of air, ρ.
Specific gravity, g.
Back-sight, $B\ S$.
Fore-sight, $F\ S$.
Intermediate sight, $I\ S$.
Height of instrument (above station), $H\ I$.
Height of instrument (above datum), } $E\ I$.
Elevation of instrument, }
Surface elevation, $S\ E$.
Elevation, E,
Bench mark, $B\ M$.
Station, *Sta.*

Triangulation station, △.
Stadia station, □.
Sounding station, ⊙.
Turning point, *T. P.*
Point of curve, *P. C.*
Point of tangent, *P. T.*
Point of reverse curve, *P. R. C.*
Point of compound curve, *P. C. C.*
Slope ratio, r.
Width of roadbed, b.
Center height, c.
Side height, h.
Township, *Tp.*
Corner, *Cor.*
Volume, V.
Length, l.
Height or depth, h.
Distance, k.
Velocity, v.
Radius of Earth, R.
Angles, β, γ, φ, with subscripts h and v for hor. and vert.
Constants, k_1, k_2, k_3, etc.
Meter, *m.*
Mile, *mi.*

Also, ft, in, yd, N. S. E. W., log, °, ′, ″, h, m, s, sin, cos, tan, cot, sec, cosec, etc.

DISCUSSION.

PROFESSOR MENDENHALL (by letter) expressed his entire approval of what Professor Galbraith had said as to the evils of an excessive multiplication of symbols, and added another reason for restricting their number, which he thought had doubtless occurred to many. It was that students, and men of experience, for that matter, are likely to gradually lose sight of the real signification of a term when a symbol is always used to express it. This is particularly true when a special name is given to the unit of the thing symbolized; and it is a strong argument against the multiplication of named units, towards which some physicists and engineers are inclined. He wished to commend what Professor Galbraith had said on the other points to which he had referred, especially his remarks on mass, weight, stress, strain, etc. In his opinion, they exhibit a sound, scientific, yet conservative judgment in the matter of the metrology of mechanics. Mr. Kent's statement that the word "strain," in its ordinary sense in the English language, "is synonymous with 'pull' or 'push'" will be found to be erroneous on investigation.

He totally disagreed with Mr. Kent in his notions of the meaning and proper use of the words mass and weight. As this subject has been thoroughly gone over before, it is not worth while to renew the controversy at this time, any further than to remark that the discussions of the subject furnish fine examples of the extent to which an exceptionally good piece of intellectual machinery may entangle itself in its own products, when the raw material with which it is fed has not been properly prepared. The attention of Mr. Kent ought also to be called to the fact that the mathematical physicists are not wrestling with this question. If it ever troubled them at all it must have been long ago. It is pleasant to know that some of them are good-natured enough to try an occasional bout with such of their brethren of the domain of applied science, as are still trying to believe that a profession, of which exact science is the corner-stone, will long encourage or submit to the use of ambiguous terms and erroneous formulas because they are "ancient and popular."

A Society whose function is the promotion, and not the retardation, of engineering education, is not likely to formally approve a symbolic nomenclature involving this.

Professor A. G. Greenhill* said he had read the report with very great interest. He thought it was thrown out in a very stimulating manner, a manner which would provoke discussion, and that he inferred to be the object of the report. He might say at the outset that he thoroughly agreed with the comments of Mr. Kent on page 73. For a professional engineer, he thought Professor Galbraith took an exceedingly academical view of the question. There is a certain divergence of opinion between the physicist and the engineer, and the speaker took the side of the engineer. He thought Mr. Kent was quite right. Take, for instance, what he said on page 75: "Professor Galbraith would restrict 'weight' to mean the force of gravitation acting on the body. This is not its meaning in common language; for a weight of 10 lbs. is not understood as the force of gravitation which acts on 10 lbs. in the United States, but the weight which would counterpoise anywhere, on an even balance scale, ten standard London pounds." He hoped that the engineer would never follow the dictates of the physicist in this matter. According to the physicist, the avoirdupois pound weight, which is specified in Acts of Parliament as a certain amount of platinum, is not that piece of platinum at all, but the pressure on the box in which it is contained. That is quite contrary, he thought, to the reading of the Act of Parliament. Acts of Parliament specify Weights and Measures; in French, *Poids et Mesures;* in German, *Gewichte und Maasse;* not Masses and Measures, *Masse und Maasse,* which would sound like the heading of some political document. He might argue that *Masse* and *Maasse* are so much alike that, if he should appeal to the German scholars present, they would support him in saying that the confusion would be intolerable if *Gewichte* were changed to *Masse.*

---

*Royal Artillery Institution, Woolwich, England.

Referring to the list of fundamental units given on page 62; "Length, L, l." As long as we speak algebraically we use those abbreviations, but when we substitute numbers and speak of "length, 10," "length, 20," we must specify the units. "Length 10, or 20" conveys no impression to the mind. He supposed that, as M. Hospitalier was addressing a congress of electricians, he meant these lengths to be so many meters (m), or centimeters (cm) and his "Mass," represented by "M," to be so many grammes (g) or kilogrammes (kg). This brings us at once to the difference between the electrician's mass and the engineer's mass. The engineer's mass is the electrician's mass divided by a gravity. "Time" is universally given in seconds (*sec*), which aresexagesimal divisions; thus, since the other symbols are on a centesimal system, the notation is a mongrel one. "Area" represented in the Hospitalier notation by "S, s" should be given in m^2 or cm^2; "Volume, V," in m^3 or cm^3; "Angle, α, β" either in radians or in degrees, minutes, and seconds; "Velocity, V" in cm/s. Then Angular Velocity (ω) would be given in rad/sec; "Acceleration, a" in cm/s^2, as it could be represented in the abbreviated notation. When we come to measurement of force, there is confusion. Is the force to be measured in gravitation units or in absolute units? The speaker thought that force is here meant to be measured in dynes; and so on for the other units.

Turning to page 70, we find among the engineer's units, the engineer's mass, $\frac{W}{g}$, which is totally different from the mass just now defined. On page 72 is the expression "tension of a belt." This, he thought, might better be changed to "pull of a belt," restricting the word "tension," as Professor Galbraith restricted the word "stress," to distributed force, the force per unit area. The pull of a belt is integrated tension; the product of the tension by the cross section of the belt. He thought it would be of advantage to make that distinction generally; to contrast tension and pressure as two kinds of stress, tension and pressure being force in pounds per square inch;

then integrated pressure should be called "thrust" or "pull."

PROFESSOR R. S. WOODWARD said that he was very much interested in this subject; it is one of great importance, especially to engineers; and he was very glad that it had been brought up by this engineering society, not because he thought the suggestions they made would be followed immediately, but because the mere fact that attention is called to the subject would restrain prospective authors to such an extent that they would give some heed to what had been done before in the way of symbols and notation, and would seek to conform to precedents as far as possible. Before passing on to some details that he wished to consider, he desired to remark that he thought it could hardly be expected that the first recommendation of the Committee, under the heading "Guiding Principles," would be followed. The recommendation is to "eliminate, as nearly as possible, all Greek symbols from engineering text-books." That, it seemed to him, is impracticable; and the chief objection to the recommendation is, that it cuts us off not only from the history of engineering works and of works on mathematical physics, which engineers must read, but also, undoubtedly, from much that will be written in the future. It seemed to him that a better way to treat that question would be to print, in every text-book wherein the Greek alphabet is used, a table of those symbols. No one need be ashamed to do that. Even if the student had never studied Greek, it would cost him but little effort to learn the Greek alphabet and the pronunciation of the Greek letters.

He thought it could be done in a day and a half by any bright boy.

The speaker then referred to recommendation No. 4: "As far as possible, take Rankine's notation as a basis for symbols to be used in mechanics." He agreed to that in the main, with the reservation that Rankine's works are now much out of date, especially the parts relating to kinetics, and to some extent the parts relating to kinematics. Some restriction might be made also with reference to the last part of Rankine's Applied Mechanics, namely, the part dealing with hydro-mechanics; although the speaker admired the book and used it as a text-book in teaching engineers formal, or rational, mechanics, yet it seemed to him that those parts of this great treatise, so eminently useful to engineers, are quite out of date, and that the student who consults them is not in line with the latest literature on the subject. It is the duty of teachers to put their students in line with the latest literature and in line with progress. So that while he agreed to this recommendation in general, as to notation and terminology, and while in most respects Rankine's notation and terminology are very good, yet they are too narrow; and, as before stated, a man who reads Rankine's hydro-mechanics gets a very narrow view of the subject. Moreover, there is great difficulty in finding out what Rankine meant. Students read Rankine's works only with the greatest difficulty. In order to get on at all well they commonly need very much explanation.

The speaker then referred, somewhat in detail, to the symbols for mechanical engineering proposed by his friend, Mr. Kent. He was very sorry that that gentleman was not present, because he wished to level some guns at him, and should be glad if he were present to reply as vigorously as he had done two years before, to some arguments adduced by the speaker at the Springfield meeting. It seemed to the speaker that in some parts of the notation proposed by Mr. Kent, there was great confusion of ideas. He wished to refer to a few of these points. First, on page 67 the symbol given for the "Angle of bend in a pipe," is the letter "i." He thought it very unhappy to use the letter "i" since this letter is much more commonly used as a symbol for numerals; moreover, it is not in accordance with the present custom of denoting angles by the Greek lower-case alphabet. Then there is given an unfortunate series of symbols for "Angular velocity," A, a, α, ω; ω seems to be the standard and classical notation for angular velocity. Then, in the next line, there is a very curious expression. "Angular movement." That seemed to the speaker to be unnecessary, if not absurd. In the next line, we have "Arc of contact (belt on pulley), θ (in ratio of length of arc to radius)." These expressions are not consistent with one another. Those two lines, he thought, should be stricken out. On the same page, we find "Coefficients of elasticity: E, in tension, compression or bending; G, in torsion or shearing." These are good enough in the ordinary operations of the engineer, but it seemed to the speaker that the engineer should obtain, somewhere in his course, a broader view of the subject, and should learn that there may be a good many more coefficients of elasticity than these two. The engineer should read enough of the literature of the subject to know that, under certain circumstances, there may be 21 coefficients. Then on page 68 D and Δ are used for "Deflection." It seemed to him that Δ should be confined, as, in most branches of applied mathematics, it is confined, to another meaning, namely, a finite difference. There is a reference to that a little farther down the page, where Mr. Kent speaks of "Difference" and gives as an example, "difference of pressure." It seemed to the speaker that we should follow precedent, by restricting Δ, as nearly as possible, to the meaning "finite difference." That restriction is pretty well recognized now in the great sciences of astronomy and geodesy, and in most branches of mathematical physics. A little farther down the page, U is used to denote "Energy." Perhaps that is not very objectionable; but in formal treatises on mechanics, U is more commonly employed to denote force function; so it would seem better to use E for energy, or possibly V, which is commonly used to denote potential energy in works on mechanics. Under the head of "Force" we strike a great source of trouble; and it was here that the speaker thought he must begin to take issue with the Society's distinguished visitor, Professor Greenhill. It seems that the word "force" in mechanics should now be restricted to one meaning—absolutely one meaning. We have substantially got rid of "live force," "dead force," "force of inertia," and the various other kinds of force (except in electricity), but especially of "living force" and "impulsive force" which were for so long a time great obstacles to progress. The speaker suggested that the word "force" should be restricted to the sole meaning "mechanical force." Then on page 69 there are some suggested notations which are, perhaps, good enough; yet it seemed to the speaker that the terms "thermal capacity" and "diffusivity," which Lord Kelvin had introduced and had used for many years, should find a place here. That, perhaps, is too technical a matter to enter into here. On page 70 the speaker noticed some details that seemed open to criticism. For example, the author suggests that the abbreviation "log" be printed in Italics. That is not in conformity with the best usage, as far as the speaker had observed. The best usage, he thought, prints those abbreviations in Roman type, as the abbreviations "sin" and "cos" are printed; and he should regret to see engineers recommend any departure from this custom.

Next comes the great bone of contention, "Mass." That is where the rub lies. During the last twenty years, there has been much discussion of this term in England which has been admirably reported in *Nature*. Those in this country who have followed that discussion have frequently been very much delighted by the remarks of Professor Greenhill. The speaker had often very much enjoyed the shrewd and brilliant way in which that gentleman had discomfited his opponents. The speaker said, however, that he was on the other side of this question. In the first place, the great objections to what has come to be called the engineer's view of the subject are, that it is a very narrow view, and that it ignores the fundamental importance of the term "mass." Of course, there is a reason for that. Our mechanics has grown up from the earth; it is a product of the earth. Had our ancestors and ourselves not happened to live on the earth, our mechanics would probably be very different from what it is, and we should not have this restriction which ties us to the earth. The engineer's system is peculiar, local, terrestrial, accidental, and it seemed to the speaker that those who teach rational mechanics should give a broader view, so that, if we should happen to spend the summer in some other part of the universe, we should know how to apply mechanics there. It might, in the future, become very necessary for us to use our mechanics. Now the man who has the narrow view of the engineer, as it has unfortunately come to be called, would not get on well in other parts of the universe. Moreover, this lack of a clear view with regard to mass is obscuring the whole issue. If there is any one idea in mechanics that is of transcendent importance, it is the idea of mass. Some of the French and German writers, notably those who are mathematicians rather than mechanicians or physicists, seem to regard mass as a sort of mathematical inconvenience. Some of those present had noticed, no doubt, in the recent admirable *Traité de Méchanique* of Appel that mass is defined as the ratio of force to acceleration. Of course that is permissible; as the French say "On se sert de ce mot et l'on comprend." But the average student, meeting that for the first time, does not understand it; and it seemed to the speaker that such a definition dodges the issue. Mass is the most important fact in mechanics; and if we go beyond our terrestrial residence, it is the most striking, the most obvious, and the most important fact in the universe—mechanical fact, at least—and that should be brought out prominently. In accordance with this view, he thought that, in teaching kinetics to students, we should always begin with the so-called absolute system. That is the only system that enables the student to get a clear and complete view of this subject. Then when the student comes to the practical work of the engineer, there is little difficulty in passing from the dyne and the poundal to the kilogramme and the pound. On the other hand, if we start with the engineer's equation, $M = \frac{W}{g}$, there is always confusion, unless the student knows the theory of dimensions well.

On page 71 he noticed a blunder; "Speed" is denoted by V, v and K, and then follows the explanatory phrase "knots per hour." The fact is that the knot is itself a unit of speed; so the "per hour" should be omitted. The only other criticism the speaker wished to make, had reference to the paragraph on page 72 where the author says, "When the Centigrade scale is used, the letter C should always be given with the temperature. When no letter is given, Fahrenheit is understood." That is asking too much of the reader. It is very little trouble to state, right on the spot, what the symbols mean. And this led the speaker, finally, to another phase of the subject, which, it seemed to him, would greatly help future writers of treatises for engineers, in getting over the difficulties which are contemplated in the report of this Committee. We can get over the most of these difficulties in any case, by supplying, in connection with the formulas, brief explanations, in fine type, of the symbols employed in the formulas. A most excellent example of this kind of work is furnished by the admirable treatise on Higher Geodesy,* by the Director of the Geodetic Institute of Germany. In most cases, in that book, the author has indicated briefly what the symbols mean; and has thus supplied, right on the spot, all the information necessary to enable the person using a formula to use it correctly and safely, without knowing anything about the rest of the contents of the book. It seemed to the speaker that it is in this direction that we should look for improvement, rather than in the direction of trying to make everybody conform to a particular system of notation which it might to-day be found convenient to set down.

PRESIDENT EDDY said that the Society was fortunate in having present a member who rarely could meet with them, Professor Unwin. They would be glad to hear from him, as a member of the Society from the beginning.

PROFESSOR UNWIN said he had seen this paper for only a few minutes. He, therefore, did not feel quite competent to enter into the controversies that this report on symbols seemed to have stirred up. He was only a practical engineer; but, unfortunately, the practical engineer has to use units of all kinds; units of different countries, units of different books, and even units adapted to the notions of people who have fundamentally different ideas about the proper use of the words "mass" and "force." If he were to say any word in this controversy, it would be that perhaps it would be best to disentangle the report on symbols from the controversy as to more fundamental questions. He did not quite see why, in the report, there should not be symbols adapted to the physicist, who takes one system, and to the engineer, who takes another. Both might be printed, and either might be used by those who like it. It had occurred to him, in listening to the discussion, that it was unfortunate that either party should undertake to snap a verdict on fundamental questions, in a report on the use of symbols. It so happened that the speaker had to read a great many books by different writers, in German, in French, and in English, and this question of a little more uniformity in the use of letters as symbols often seemed to him important. One has trouble often enough in learning a new notation, when reading a new book. Some years before, the speaker had even suggested to a committee that was dealing with units very nearly the same thing that this Society is now doing. It was unfortunate to suggest it to that committee, because it was concerned with the fundamental questions much more than with mere conventions about notation. He certainly thought that some good might be done, if the example given for future writers to follow were any possible, convenient use of symbols. The speaker's point of view was that the real question before such a committee is merely one of convenience; and if the Committee would look at it from that point of view, perhaps some of their labors might be lightened. The speaker added that he was very glad to be able to come once more to a meeting of this Society. He saw the Proceedings, and was very much interested in the work the Society is doing.

---

* Mathematischen und Physikalischen Theorieen der Höheren Geodäsie, von F. R. Helmert, Leipzig, 1880, 1884.

Professor Macfarlane wished to call attention to what is printed at the bottom of page 62, referring to symbols for electrical quantities. The Committee on Units and Standards, of the American Institute of Electrical Engineers, after considering Professor Jackson's proposed notation, says, "The Committee has carefully considered your communication and strongly recommends the system of notation and symbols which was prepared by the Committee on Notation of the Chicago Electrical Congress, and which is printed as an appendix to its proceedings." This system, then, was recommended by a committee of an International Congress; it has been coming more and more into use, and it is now more in use than at the time when Professor Jackson wrote the report. The speaker thought the objections to the Hospitalier notation were very unimportant. One of the objections was, that there are some script letters in the system, such as the one for magnetic induction—described, the speaker believed, as French script. A good many English and American writers use a block *B* for the same quantity. The only other objection that the speaker had seen was that *I* is used for current, instead of *C*. These seemed very slight objections. If any other form of letter could be used, that might be an improvement; but the system as a whole is logical; there are no such defects in it as in the symbols of Mr. Kent; and the system is continually coming more into use. If this Society should make any recommendation on the subject, he hoped it would be to adopt the Hospitalier system, as far as electrical symbols are concerned.

PROFESSOR CALDWELL agreed fully with the last speaker that it would be much better to cast the weight of our influence on the side of what has already been done, than to try to set up a new system, which might have superiority in some slight details, but which would add still further confusion to the confusion which is even now the most prominent feature of the case. He did not see why this Society should not recommend the system advocated by the Chicago Congress, rather than try to make any improvements.

METHODS OF TEACHING.

BY W. H. P. CREIGHTON,

Professor of Mechanical Engineering, Tulane University, New Orleans, La.

The writer enters upon this subject with much diffidence as there are many here with more years and more experience than himself. The subject is an important one, and it is to be hoped that it will be taken up again, as it is worthy of a very extended discussion.

The solution of almost every engineering question lies in a compromise. The proper tuition of an engineering student is no exception to this; a compromise between education and instruction must be made in his case to obtain the best results.

The difference between education and instruction may be illustrated by two examples. The first is taken from the U. S. Naval Academy, where "instructors" do not instruct. The method of educating employed there, being extreme and novel, may be of interest.

The summer vacation of three months is given up to practice cruises or practical work in the shops. From October until June the morning contains two periods of two hours each. A subject is assigned to each period. During one hour of the period the student may study, and he must recite during the other. In the afternoon is another period, and to this is invariably assigned laboratory or shop work, or a study of less importance than those assigned to the morning hours. The cadets, having dinner at noon, are less capable of heavy work in the afternoon. Laboratory or shop work, or monthly examinations, occupy both hours of the period.

For an hour and a half before supper, students have drill or practical work of some character. At night, a study period lasts from eight until nine-thirty. At ten, all lights are out, and an all-night inspection is made to see that they are not relighted.

The classes are divided into sections of fourteen members. Sometimes half of the section, sometimes the whole section, is sent to the blackboard. The instructor assigns a few of the most difficult problems in the text, and then selects his other questions or problems from other text-books, or from collections of Cambridge or Oxford examination questions. In the engineering sections, the instructors have their questions written out on slips of paper, and the class is invited to come up and take problems. The expressions of the faces of the cadets as they turn over the slips and read their questions, reveal their thoughts perfectly. Some smile; but others furrow their brows while trying to discover some relation between the problem in hand and the text studied the night before.

Cadets very rarely ask questions of the instructor, and anything like currying favor is instantly frowned down by classmates. Those who stand high ask no questions of their fellow students. Competition for class rank is good-natured, but keen, as much depends upon it, and "Ask no favors" is the motto. No matter how long or how difficult the lessons, no matter how low or how unjust the mark, there is no complaint.

Very few lectures are given; and in examinations the questions involve applications of the lecture, rather than the lecture itself. The cadet never attends more than three recitations in one day, but the amount assigned for each recitation would startle the ordinary student. The time for study is limited. If a cadet who stands high attempts to study out of assigned hours, it is prevented by his classmates. The latter say, "If you who stand high cannot do the assigned work, what can we do?" As a result, students learn to concentrate their efforts and to avoid "Building castles in Spain." Pure memory work fails, as questions involving applications are given more often than text questions; nevertheless the memory is exercised, as the text must be remembered. The most difficult examinations are invariably those in which the students are invited to bring in all the text-books or note books they wish. The examinations are long and thorough, and the cadet that receives a perfect mark must know at a glance that he can answer every question; and even if he does not waste a moment he will not finish the last answer until the bugle blows. The time is so short that cadets invariably bring four or five sharpened pencils into the examination room. Further, a sharp cadet always reads the whole examination paper and answers first any question which he is sure of answering perfectly.

I have presented this as a method of training; each of you may pick out its defects and its advantages. Let us contrast this with another method which is favored by many "practical people."

In England, young boys are sent to the "works," where they serve as apprentices, being advanced, according to their merits or their influence, from position to position. Meanwhile, they obtain such theoretical knowledge as opportunity, industry, or chance allows them. I have not space to go into the difficulty of studying after a hard day's work, of solving theoretical questions without a knowledge of other theories that precede.

An opportunity for comparison was given some years ago, when a Naval Academy graduate was sent to a large shipyard to learn naval architecture. He was put at work in the drawing-room, where his ignorance of ships made him the laughing-stock of the apprentices. The latter had been in shipyards all their lives and knew "all about ships," at least in their own estimation. So, at first, our cadet traced drawings of little importance. At the end of the first year he had advanced a number of rounds from the bottom of the ladder and had displayed knowledge at unexpected places. At the end of the second year he was well above the middle of the ladder, and he had ceased to be a laughing-stock. At the end of the third year he had distanced all competitors; and during the fourth year he was next to the chief designer.

During the first year our cadet lacked a knowledge of facts, and his training was of no immediate benefit. But, with a solid training in theory, picking up facts is not difficult; hence his rapid advance was not so marvelous as it seemed to his brother apprentices.

Instruction is often confounded with education. By instruction, the student acquires a large amount of information, or a large collection of facts, with little mental effort. He listens to a good lecturer who, starting on a common ground, ascends from fact to fact so gradually that the transition is not perceived. Many medical and law colleges follow this plan.

To educate a student is to train him to observe carefully, to reason closely, to use judgment, to remember accurately, to be careful, accurate and conscientious in his work. If all these can be accomplished best through the study of subjects that are of no utility in after life, let us use that method of educating our students. But if, on the contrary, we can educate as well, if not better, while giving our students knowledge that will make them useful, and perhaps make them the peers of those who have given us the marvels of this century, ought we not to do so?

True teaching, in any subject, whether in the laboratory or the recitation room, should keep a true balance between instruction and education. Economy of time requires that a student should be taught those subjects that he will use in after life. But this can seldom be done directly, as few students have definite plans for the future. In most cases, then, it is best to educate the student while giving him a store of knowledge that must be of use to him in after life.

Shrewd shop managers, when they want visitors *not* to see, are very careful to show everything (a little hurriedly) from the sixth floor down. And when the visitor is politely bowed away from the door, he has very general and vague ideas of what he has seen. About the only definite impression he retains is that he went through the shops and was nicely treated. Many instructors follow a similar plan, dwelling with impartiality on important things and on unimportant ones, so that at the end of the course, the student knows that he "studied" such and such subjects, but he does not know much more than that.

In connection with the above, I wish to call attention to that great bugbear of the student, "formulas." The books on trigonometry, calculus, analytical mechanics, and thermodynamics teem with them. A single formula is presented in half a dozen shapes. The student asks himself, "Which one shall I memorize?" Left to himself, he memorizes them all to-day and promptly forgets them all to-morrow. The instructor should determine which are the fundamental formulas, and should require the student to memorize them just as we have memorized the multiplication table. In working problems, the student must start with one of these fundamental formulas and derive the special ones desired. Where the student thinks despairingly that there are hundreds of formulas to remember, there may be in reality only half a dozen. These form the backbone of the subject, the subsidiary formulas being the ribs attached thereto. These remarks are especially applicable to organic chemistry, trigonometry, and calculus.

I have had many students whose knowledge of trigonometry or of calculus would be about equal to what your knowledge of a new story would be if you had read the story diligently, chapter by chapter, but taking the chapters indiscriminately, now from the beginning, now from the end of the story. For the sake of clearness, the connecting thread that runs through every subject must be kept before the student.

Many instructors fail to understand that we rise from the concrete to the abstract. A falling apple, we are told, led Newton to the discovery of the law of gravitation. Each new subject taken up by a student contains, to him, a new language, a new line of thought. It is a mistake to place before him a large number of abstract principles, when beginning a new subject, as they discourage him. Calculus, for example, is regarded by most students, the world over, as a sort of mathematical juggling. By beginning with graphical illustrations, there is presented to the student something that he can grasp, and he obtains ideas which he can broaden as his acquaintance with the subject becomes more extended. For example, the $d(x^2)$ and $d(x^3)$ can be shown graphically, and the student will then accept the differentials of higher powers by analogy. Similarly, the plotting of curves and their tangents, by means of cross-rule paper, illustrates $\frac{dx}{dy}$, $\frac{d^2x}{dy^2}$, etc.

Easy problems, that can be represented graphically and worked by calculus, can be given, to show students how calculus may be applied. After the student has obtained a general idea of the intent of calculus the regular proofs can be given, and will then be studied understandingly by him. Graphical representations of thermodynamic quantities are especially desirable; and the methods of Northcott, of Cotterill, and of Wood are especially to be commended.

Judgment comes from constantly judging; and this will never come to the student if the instructor is constantly at the student's elbow to correct mistakes. Do not try to cover much ground by setting up the student's apparatus so that all he has to do is to open a valve or two. If a student takes more than a reasonable amount of time for his work the laboratory is no place for him, and his failure is a reflection on the laboratories and shops of the preceding years. Shop work is generally placed early in the course, and its main value is not to teach a few facts about welding or screw cutting, but by far the larger part of its value lies in the fact that it is an interesting means of teaching the student to think, to judge, to be accurate, careful and painstaking in his work. And if the student who has had shop work does not do better work in the various laboratories than those who have had no shop work, then not the shops, but the instruction therein, is a failure.

Students should be trained to the principle that all work should be just as accurate as necessary. In business, exact calculations cannot be made. Nevertheless, all good business men weigh all known conditions and estimate the unknown ones. Engineering education should make good business men; for, in pure mathematics, the conditions are exact and an exact answer is required. In applied mathematics, design, etc., the conditions are not exact and the strength of the materials used is not exactly known. The laboratories should be used for drill in the above principles, to develop common sense and judgment. A graduate of a well-known school was ordered to work out the weight of a condenser. After three hours' painstaking work he gave the answer as 63,235.25 pounds. Two minutes' work by his superior showed that the true result was close to 16,000 pounds. It was then found that the 63,235.25 was cubic inches instead of pounds, and that our bright graduate had forgotten to divide by four. In his anxiety to obtain an absolutely correct answer, he made a serious error that vitiated the result.

The shops and laboratories form necessary adjuncts to enginering courses. Why? Originally they were added to give to students practical experience instead of pure book-learning, otherwise pure memory work. Their value was intended to be largely instructional, or utilitarian, in character. Many people yet regard them in this light and desire the work therein to be still more "practical" in character. Many think that the work therein should be carried on just as it is carried on in real shops. Some think that actual work in construction should be done; others want the piece-work system or the jig system to be fully ventilated, so that the student shall "know something" when he graduates. All these lose sight of the fact that the imitation is never the real article; they lose sight of "lack of time, mental capacity, youth, manual skill, and cost;" and what is of very much more importance, they lose sight of the fact that the best value of the shops and laboratories lies not so much in the matter that they teach as in their training. Subjects that are purely utilitarian must give way to subjects that have high educational value and are at the same time useful. This is especially true in the undergraduate years. For example, the foundry is of more importance than the forge shop, because the student must think more in the one than in the other. The great educational or training value of the shops and laboratories was not foreseen, but it developed itself; and their value in this respect must be kept in mind by engineering instructors and professors. The great growth of engineering colleges makes this more important, as there is no room in true engineering work for a large proportion of the graduates. Teach the student how to study, how to think, how to look up facts, and, with a thorough knowledge of the principles underlying engineering questions, turn him adrift to pick up by himself the facts of the particular line that fate assigns him after graduation.

DISCUSSION.

PROFESSOR C. FRANK ALLEN said that there was opportunity for much to be said in relation to methods of teaching, and he had hoped the paper would more directly attack in detail the various methods which had been suggested to the Secretary: by text-book, by lecture, by design, by laboratory, by memoir. There are several things to be looked to, if we would reach the best results with students. It is true in a general way that the student receives benefit in proportion to the amount of work that he does. On the other hand, on the principle that "all work and no play makes Jack a dull boy," it is essential that, in compelling the student to do a large amount of definite work, care should be taken that he is interested and stimulated in some way at the same time, so that the task shall not be too dry and hard. One of the advantages of teaching by several methods, especially where the work is done by different teachers, is that in this way the student's interest is stimulated to an extent that is not possible where a single method of teaching is used and nearly all the work is done by one teacher. We do not always appreciate the value of the teacher's influence, outside his teaching to a large degree. It is a fact that some other professors in the department are able to reach certain students who do not yield at all readily to the speaker's teaching, while, in other cases, his own teaching stimulates students not reached by the other professors. The speaker agreed with the writer of the paper, that it is desirable that a paper be written and presented at some future meeting and the value to be derived from the different methods definitely and fully set forth. Many excellent points were brought out in the paper just read.

Professor Thomas Gray agreed with Secretary Allen as to the excellence of this paper, and also with regard to the desirability of having a somewhat more extended discussion of the different methods of placing subjects before the student. It is impossible for the members of the Society to treat such subjects very satisfactorily in a discussion ; and, therefore, it is desirable that some one should undertake the collection of comparative information with regard to the results of the different methods of teaching the subject to the student. The example given in the paper, of the student who had received the theoretical instruction before going to the English ship yard, suggested the question, whether it is better to send the boy to college first or to the shop first. The speaker was in doubt on this point, but he thought there is some probability that the boy who serves at least a part of his apprenticeship before going to the college will distance the other students there as much as the technical graduate distances the apprentices in the shop. The practical knowledge that a boy obtains during his apprenticeship is of very great value in enabling him to follow intelligently the objects of the teacher in the college. In making such a comparison as this, it should be remembered that the young man who has passed through the technical college is probably considerably older than the apprentice who enters the shop before going to the technical college. The comparison is not quite fair, whether, in the one case, the technical student is regarded as having the advantage, or, in the other case, the apprentice as having the advantage. The speaker's own experience was the reverse of what is the present custom; and he thought there are very considerable advantages in having practical knowledge of a subject before studying its principles. This involves, however, the serious disadvantage that during the apprenticeship period the knowledge obtained in the school must be kept up in order that it may be available for use on entering the college. That entails a considerable amount of study in the evenings; but for the greater part of the year there is very little difficulty in doing this, where there is willingness to study.

President Eddy stated as to the particular point brought up by Professor Gray, that there had been, before a joint meeting of the American Institute of Mining Engineers and the American Society of Civil Engineers, in 1876, a joint discussion on this subject. The discussion arose on an address by Alexander Holley, in which he had advocated the position, taken to-day by Professor Gray, that it is desirable that the apprenticeship work should precede the college work; and the papers that were presented at that meeting were collected by the Secretary of the Institute and were published in a pamphlet of very great importance. The discussion was participated in by a large number of the leading American engineers of the day. It was a very interesting and valuable discussion of this very question. That discussion, however, treated the general question, rather than the especial one which has been treated in the paper before us, of the manner of presentation in the course of our technical instruction. Upon this all would agree that we should have further light.

ELECTIVE STUDIES IN THE REGULAR ENGINEERING AND TECHNICAL COURSES.

BY HENRY S. MUNROE,

Professor of Mining, School of Mines, and Dean of the Faculty of Applied Science, Columbia University, New York.

Modern civilization, with its wide range of material requirements, has forced upon mankind an equally wide range of occupations. The field of labor, as far as the individual is concerned, is becoming more and more specialized. This is particularly true of the engineering professions and of technical occupations in general. Civil engineering, mining engineering and mechanical engineering show a marked and increasing tendency to subdivide into new and special lines of work.

Most of the older technical colleges, abroad as well as in this country, have recognized this tendency and have multiplied the number of their courses in order to train men for many special lines of work. Some of our leading educators have thought it necessary to protest against this movement, and have claimed that we have already too many courses of instruction. They would have us confine the work of the colleges to a limited number of courses, and postpone specialization to the after years of professional life. No one, however, will go so far as to recommend a single course of instruction for all engineers, and it will be generally admitted that several courses, that some degree of specialized instruction, is necessary.

Two questions then rise for discussion :

1. How far shall special instruction be carried in

the technical colleges, and how much shall be left to be obtained in professional practice after graduation ?

2. What is the best method of organizing the instruction in the professional colleges to secure the amount of specialization desirable ?

The following conditions tend to limit the possibility and the extent of specialization in the schools.

The education given must be complete and thorough in all fundamental and necessary subjects, and it must also have breadth and include a sufficiently wide range of subjects.

If by reason of environment and the lack of proper preparatory schools it is necessary to make good the deficiencies of the students in elementary subjects, it is evident that one or both of the above requirements must be sacrificed if specialization is attempted to any great extent.

In addition to these educational requirements there are further limitations of a practical or economic character. Instruction in any new subject, or special instruction in a subject already given, demands either extra work on the part of some member of the faculty, perhaps already overburdened, or, more often, an addition to the teaching force. With a small faculty, therefore, it is impracticable to go far in the direction of specialization.

Again, a new course of study usually requires laboratories, collections and other apparatus of instruction, and rooms, or even a new building, to accommodate these additions.

Finally, it is impracticable to add to the teaching force or the equipment of a college for the sake of a very few students.

With these educational and economic limitations in view, it is evident that a large number of courses, or great specialization in technical instruction, can be afforded only by a well equipped institution with a large faculty and having a favorable environment, with large numbers of well prepared students to draw upon. To attempt any great degree of specialization under less favorable conditions is to invite failure.

These limitations being admitted, the following advantages may be claimed for highly specialized instruction, or for the institution offering a large number of courses of study.

The education which best fits a man for his future career will be most profitable to him. If we know just what the future work of a student is to be it will be possible to devise a scheme of study, which, without sacrificing breadth or thoroughness, will best fit him for that work. If, for example, a young man desires to make a specialty of electro-metallurgy, he should not be called upon to choose between the course in mining engineering and the course in electrical engineering, nor should he be compelled to take the course in mechanical engineering, but, if possible, he should be allowed a combination of the three courses, and the scheme of instruction should be sufficiently elastic to permit this and other similar combinations when necessary. In most institutions the studies of this particular combination can be completed in five years; but if a sufficient number of students desire electro-metallurgy, a four years' course should be arranged for their benefit.

An institution which offers the special education needed by any given class of students will naturally attract that class; and the institution tendering the greatest range of courses of study, other things being equal, will prove useful to the greatest number of students, and of the greatest value to the community.

The full efficiency and usefulness of a large faculty, and of each member of that faculty, can be secured only by highly specialized instruction. With a few rigid courses only, the number of subjects that can be offered by any professor is necessarily limited to those included in these courses. With the widest possible range of choice offered to students, either under the elective system, or by many courses, the number of subjects that may be offered by any professor is limited only by his capacity for useful work. In each department, long courses may be provided for students requiring a thorough knowledge of the subject; short courses, for students to whom the subject is of minor importance; and advanced courses, for those desiring to make the subject a specialty.

The possibility of thus offering both long courses and short ones is of great advantage to the institution. When a single course of lectures only is given in any subject, it is difficult or impossible to adapt the instruction perfectly to the wants of the different classes of students. For example, a course in metallurgy, designed for the needs of the mining engineer, will be much too long and detailed for the student of civil engineering, and only imperfectly adapted to the needs of the student of chemistry or of mechanical or electrical engineering. By short, and long, and special courses in metallurgy, the needs of all classes may be met, and the time of the student may in each case be used to the best advantage. The more the instruction is specialized in this way, the more perfect will be each course.

The introduction of new courses of study often tends to improve and strengthen existing courses in another way. For example, courses in civil engineering and in mining engineering should include some instruction in mechanical engineering. The establishment of a course for the degree of mechanical engineer, in the same institution, with mechanical laboratories and shops, makes it possible to give this instruction to the civil and the mining engineering students under most favorable conditions.

In a similar way, the addition of a course in electrical engineering, tends to strengthen all the other courses in engineering.

The adoption of a high degree of specialization thus offers to each student exactly the education best fitted to his needs, adds to the usefulness of the faculty, and tends to promote the growth and development of the institution both from the educational standpoint and on the material side.

The modern university offers the individual student as much work as he can compass in a lifetime, from which to choose the four or six years' work adapted to his temperament and needs. Such an institution numbers its faculty by hundreds and its students by thousands. Why should not the technical colleges aim at like development?

We may proceed now to the second question. How may the instruction best be organized to secure the high degree of specialized instruction which seems to be desirable? There are three systems in use, by which the student's course of study is determined.

1. The elective system.
2. The course system.
3. The combined course and elective system.

The elective system for special students, so-called, has been in use and has had a more or less complete trial at most of our technical institutions, side by side with the course system. As a result of long experience, these special students have been shut out from some institutions, and are admitted to others only in limited numbers, and with their freedom of choice much restricted.

The main objection to the elective system in engineering education is that the final decision as to the necessary preparation for his life work rests with the student himself. In rare cases he may evolve a scheme of instruction better than that which could be devised for him by the combined wisdom and experience of his instructors. As far as he avails himself of the advice of his elders, and as far as he is controlled by wise and carefully framed regulations, he may escape serious mistakes. We may prevent him from taking subjects for which he is not properly prepared by insisting upon the proper sequence of studies. We may secure a certain degree of breadth to his course of study by insisting upon a proper association or grouping of studies. We may prevent unwise or undesirable combinations, by special rules, or by a prearranged conflict of lecture hours, or by the exercise of a veto power. We may continue this process until the student's choice is so limited and so carefully guarded that he cannot make a mistake, and must take a course of study perfectly satisfactory to his instructors. When, however, this result is reached, the system is no longer elective, but is the course system, more or less disguised. Short of this, the element of student responsibility and the danger of unwise exercise of that responsibility cannot be wholly eliminated ; and as far as this remains the elective system contains an element of weakness.

The administration of the course system with elective studies should be much simpler than for the elective system. In a large institution, under the elective system, the advisory officers may be required to pass upon a thousand courses of study, for as many students, in the first week or two of the term. Those of us who have spent anxious years in perfecting a single course of study in civil engineering, in mining engineering, or in mechanical engineering, are able to realize what this means. The work must be done by a small committee, as the energy and executive ability required to do it properly are not common. Even if abundant time were available the task is well-nigh impossible, and mistakes must be many and serious. The difficulty is increased from the fact that the executive officers are called upon to pass judgment in each case on a single year's studies—a detached fragment only of the student's course of study. It is probable that the best and most successful advisory officers consciously or unconsciously adopt a course system, and formulate, each in his own line, a course or a series of courses of study, which, with slight modifications perhaps for the individual, the students are compelled to take by suitable regulations, and by the exercise of tact and hypnotic influence if necessary.

The administration of the course system is much simpler and more likely to be successful. A series of courses, ten, twenty or thirty, with variations if necessary, are worked out to take full advantage of the resources of the institution. This will be the work of years. After this has been done it is a comparatively simple matter for the student and his advisory officer to select the course best adapted to his needs, and to consider any minor changes and substitutions, in the case of one or two studies, that may seem advisable.

The combined course and elective system has been in use for many years at several institutions, and if developed to its full extent would seem to have all the advantage of the elective system, in permitting almost indefinite specialization, while securing the breadth, completeness and thoroughness of carefully planned courses of study.

In some institutions, as at the University of Michigan, the required studies of a course are arranged to occupy a certain proportion of the student's time, and he is free, under proper regulations, to take such subjects as he may elect, to make up the balance of the hours required for his degree.

In other institutions, as at the Massachusetts Institute of Technology, and at the technical schools of Columbia University, the courses are planned to occupy the whole time of the student, but certain studies may at will be replaced by certain other specified subjects.

The second plan may be developed so as to permit as great variation in the regular courses of study as the first, and has the advantage that the initiative is taken by the faculty and not by the student.

Either of these plans is a great improvement on the rigid course system, in permitting specialization in desirable directions; and either plan avoids the disadvantages of the elective system, though necessarily imposing a somewhat greater restriction on the liberty of choice of the student. The second plan, if desired, can be so modified as to permit the student to suggest substitutions of one study for another, or even new combinations of courses to suit his particular needs. The element of student initiative and of the responsibility of the student for his own course of study is very attractive; and as far as it can be grafted on any system without danger of abuse, it is a distinct gain.

In an institution offering many courses of study, one of the most difficult problems is the arrangement of a scheme of hours for lectures, recitations and laboratory work. In the elective system, a poorly devised scheme may seriously limit the student's choice of studies, and may force him to adopt undesirable combinations in order to occupy his time.

A great advantage of the course system is that each combination of studies and each class of students must be provided for in the scheme, and thus every student is able to pursue his studies in proper sequence and to the best advantage.

In the elective system, it is manifestly impossible to provide for every individual student or to arrange for all possible combinations of studies; and this fact in many cases deters the officers in charge from giving to the details of the scheme, the careful attention that is desirable for the best results.

In the course system, the proper arrangement of the scheme of hours is a necessity and is accomplished at any cost. Elective or alternative studies are naturally put in the same hours as the studies they are to replace, and a scheme of hours is thus built up which permits the student to take full advantage of the opportunities offered.

DISCUSSION.

PRESIDENT EDDY stated that this question had been before the Society at its last meeting and had been very extensively discussed in some of its aspects. The question is one of very considerable importance in engineering colleges, and one which is being solved in very different ways in different colleges. He thought comparison of opinion upon that subject to be of vital importance to many members of the Society.

PROFESSOR C. FRANK ALLEN said that on the whole it seemed to him the positions taken by Professor Munroe on this matter were substantially sound. He did not think that the subject had been attacked before in quite the same spirit, and with the same freedom, and from all sides, as it had been attacked by Professor Munroe. The paper presented by Professor Wadsworth in 1895 dealt with the elective system exclusively, and largely with a particular system that was in use; and perhaps the general effect of that paper was in the direction of that particular system rather than of elective systems in general. It had seemed to him that the possibility of a considerable choice of courses of study, or of options, might not be a disadvantage. It is well recognized that the training is the essential thing; but there are so many subjects in engineering work that are admirably adapted for training purposes, that it seems wise—certainly it is not unwise—to take up such subjects as will give the student, in addition to the training, some fitting for the work that he expects to do later; and there results from this, if all goes well, the advantage that, while securing the training, the interest of the student can be fully maintained. Of course fundamentals should not under any circumstances give way to optional studies.

Professor Sackett said that the paper assumes a considerable decision on the part of the student, with reference to his college work. One of the statements is that if we knew the work that the student is to pursue, we could plan a course of study which should lead him to that particular subject within a year or two. A prominent engineering journal gave some statistics concerning graduates of engineering colleges. Of course those statistics were confined to students of an earlier date, that is, to those who had been successful from the point of view of business men; and the journal emphasized the fact that about 50 per cent. of the graduates of engineering colleges drifted, in the course of time, into other work; they became men of affairs, heads of corporations, managers of railroads and of manufacturing enterprises. The journal seemed to offer the idea that the engineering courses afford the best preparation for business life. Whether that were true at the present time, the speaker did not know; whether evolution has made the engineering courses any less a preparation for business life, he could not say. It seemed to him that they are still a first-class preparation for many kinds of work besides engineering ; also that the number of those who drift into other occupations indicates that the student at the time of entrance upon his special course is not as yet able to tell what his future work will be. The speaker wished to hear opinions as to whether engineering courses are and ought to be the best preparation for business life.

Professor Johnson thought that it will be more and more the case that our graduates will go into the industrial pursuits, into the management of industrial works, railroads and other large business enterprises He thought that the habits which the engineer forms in college and in his constant practice in connecting causes and effects, and in predicting results from any given set of causes or conditions, must be extremely valuable in business life. To foresee the results of any given set of conditions is a responsibility that seems to rest upon the engineer, from the very fact that he calls himself an engineer. The engineer thinks that he fails if he does not to some extent foresee the results of each new undertaking, whereas the business man does not usually recognize any such failure whatever; neither does the ordinary mechanic. These men say, "We expect to fail a great many times before we succeed," and they start with that expectation. They use what might be called the structural method of testing the facts in each case ; they build machines and try them, throw away several, and fully expect to do so. The engineer does not expect to do that.

The speaker thought that our graduates will more and more follow the pursuits that are not recognized as strictly professional; and for that reason the more general, or mixed, courses in the engineering colleges are perhaps excusable. If it were known that a man would follow a professional line in a certain comparatively narrow specialty, then that man ought to prepare himself very fully along that line; but it naturally cannot be known what line he will follow, even though he remain in professional work; for the civil engineer goes into mechanical employment, and the mechanical engineer into civil engineering employment. In fact, the speaker thought the graduate is quite as likely to go out from professional lines altogether. The value comes, then, in the training obtained in the school of applied science, or as the Toronto school is named, School of Practical Science, and it does not matter much which particular line of practical science the student pursues in the school. In any course he gets the training, or ought to get it, about equally well on any of these lines. The speaker thought the time is coming, and coming rapidly, when it will not really matter so much what course a boy takes. The important question will be, Has he had a good, thorough training in some course of practical or applied science?

PROFESSOR KIDWELL regretted that Professor Wadsworth, the author of the paper presented last year, was not present to discuss the paper just read. He himself, however, would discuss some of the points brought up. He had heard many objections urged against the elective system; it seems, however, one must go away from home to learn the whole truth ; he heard now for the first time that to the other objectionable practices of the faculty of which he was a member, hypnotism and mesmerism had been added. He did not believe that these factors entered into the matter, or if they did, he had abundant evidence that he himself had not been a successful practitioner of them. The speaker did not wish to take time for discussion of all the numerous conclusions reached by Professor Munroe, but would confine his remarks to certain points which related to a paper read last year, and concerning which there was misunderstanding, as he had found from conversation with some members. There was an impression that the author of that paper was convinced that the system he put forth was *the* thing, the only thing, a pill that all should take, and in the end must take. The speaker personally knew that this impression is wholly in error ; that the author of the paper of last year wished merely to state his belief that the system is the one which best answers the needs of the college over which he presides ; this is exactly in line with the ideas advanced in Dr. Murkland's paper. That the system would be equally good under any and all circumstances, the author of it did not claim ; and this fact was explicitly stated in his paper. As to looking up the courses, the necessity of arranging hours properly, the conflict of lectures, and similar troubles unearthed by Professor Munroe, they were all novel to the speaker ; he had encountered no such difficulties, nor are they a necessary consequence of the elective system. It is perfectly true that in working out the scheme, all such matters must be thoroughly considered and provided for at the beginning, otherwise there will be trouble and the inevitable changes later. This is no objection whatever to the system itself; the same trouble would occur in any other course, although, perhaps, in not exactly the same way.

The speaker did not consider that Professor Munroe's plan of providing a large number of set courses was in any way superior. It can be employed only in an institution which has a very great number of students and a faculty of a size impossible to all except a few schools. Furthermore, in the end, the difficulty remains that courses cannot be provided in sufficient numbers to permit every applicant to prepare himself, with the least expenditure of energy, for what he purposes to do. The student is finally forced into the set course which comes nearest to his wants—sometimes after making changes—lopping off here and there. The speaker believed this trouble to be far worse than anything yet encountered in the elective system under which he was working.

There is, further, an erroneous impression that the elective system is free to the extent that one can, without limitation, take just what he pleases. No such liberty is allowed, and it is unnecessary to say that any scheme permitting it would be an educational farce. There is a superior and an inferior limit to the amount of work one may take, judged in each case by the student's personal equation. Further, the sequence of studies as pointed out in Professor Wadsworth's paper is rigidly followed. The student himself determines the point at which he desires to emerge from the educational woods; and once this is decided upon, a large part of the path he must travel is definitely settled. In consequence of this, some raise the objection that the election exists in appearance only, and if that objection were urged, he thought it would have to be admitted.

One gentleman present had echoed Dr. Munroe's statement that the student thinks he is electing while in reality he is not; that it is hypnotism, in fact. While the idea of hypnotism certainly originated in the imagination of these gentlemen, it must be said that, even supposing for a moment that this view were correct, the fact that a man could be forced to take a course of this kind with perfect satisfaction would be in itself an advantage which should not be underestimated. Another point of advantage seemed to be entirely overlooked. Having once established a rigid system, one must immediately decide between two things: whether to establish in each and every subject a certain high standard that every student must reach or fail to graduate; or to pass him through if he retains a high proficiency in the majority of subjects, yet owing to lack of ability in certain lines is weak in other subjects. The speaker thought that this difficulty could not be avoided in any rigid system, without working great hardship to the student and punishing him for a fault for which Nature alone is responsible.

The speaker stated that there were many other points of this kind, but he would not weary the meeting by mentioning them. Careful study of Professor Wadsworth's paper and the discussions upon it would shed a good deal of light on some of these points. He would, however, mention some cases which came under his observation, in line with the remarks of a previous speaker. Something had been said as to the necessity of taking a course of liberal studies along with engineering. The speaker was happy to say that the reverse method is becoming more and more common. He knew of cases where men who had no intention of following engineering as a profession had taken a strong, stiff course in an engineering college, simply as a preparation for business life. They felt that the training they got and their contact with the material things of life would repay them for the time spent. The speaker had conversed with several of these men some years after graduation, and as far as their experiences went their choice had been excellent.

Professor Carpenter. It would seem from the remarks of Professor Kidwell that each one's opinions of the elective system are largely founded on individual experience. For instance, Professor Kidwell's views differed from the views of the speaker, which are based on his own experience, and which correspond almost exactly with those stated by Professor Munroe. The speaker had experienced nearly all those difficulties which were mentioned in the paper in relation to the arrangement of hours, and this had really acted, in a certain measure, as a bar to prevent the selection of certain electives; and that, too, in spite of all precautions against conflicts. This was mentioned merely as one of the practical objections that had been experienced, and which probably must be experienced in a college with a great many students.

Professor Ordway. It is true that if many electives were followed, students would generally choose to omit the liberalizing studies, the humanities, which, in accordance with the consensus of opinion, the speaker thought should be studied to a certain extent. His experience with students was that a great many of them would like to omit German or French, or political economy, or something of that kind, which they thought would be utterly useless in connection with their business, but which they might afterwards find to be of considerable importance. It seemed to the speaker that, for the sake of insisting upon some of those studies, we should not allow too much of the elective system. It is well enough, perhaps, to allow some elections in the purely professional subjects. One thing that must be remembered is that a great many of these men, as has been stated, go into other lines of business in the course of time; and why? It is really because an engineering profession cultivates the executive ability of the man. We all know that a man in that profession has a great deal of work to actually carry out; and in that way he develops a strong executive ability. In many cases the men who go into business, are decidedly deficient in that respect. This may be exemplified by some of the presidents of our literary institutions—men who had had merely a classical education and did not know really how to administer the work of their own institutions. The consequence had been, in many cases, that there was a continual call for money, which had not always been properly expended. Again, as to manufacturing concerns, the speaker recollected that in many of the cotton manufactories, when they were first established in this country, the men who were put in charge were lawyers—men who had no conception whatever of mechanical operations; and that, he thought, may still be done to a certain extent. There are men who get into such places, not because they have executive ability, but rather because they have influence in their favor, more than anything else. The speaker thought, however, that this influence will not count for very much when it is found, as it now is found, that engineers should be in charge of such things. He thought, therefore, that engineers are likely to be called generally to have charge of large operations; and they should be men who are not too narrow; they should have something liberal in their education; and for that reason the speaker would not allow, in the early steps of their education, too much election. A certain amount, however, is certainly very desirable.

President Eddy said the Society would be very glad to hear a word from Professor Greenhill on this subject.

Professor A. G. Greenhill: Does the quality of the thing alter with the name that is given to it? This has been a subject of disputation among many able schoolmen. The speaker thought he noticed in the remarks of Professor Johnson that some such distinction was made, because what is called an experiment when performed by the theorist is called a failure when carried out by the practical man. Here we have the same thing, differing only in scale. Of course, the more the practical man can be persuaded to carry out his experiments on a small scale, the more he approximates to the theoretical condition. That of course is a desirable state of things, and the practical man thereby avails himself of the resources of modern science. Napoleon said that the greatest general is the one who has committed the fewest mistakes. A successful practical man might be measured in the same way. To quote again from Napoleon: Measure the strength of a chain by its weakest point, and the strength of a man by the strongest.

PROFESSOR KIDWELL said he would like to refer to a few additional points. It must be understood that in his institution there are none of the so-called liberal studies. While this might seem strange coming from him he was not responsible for it. The faculty had been compelled to make every course strictly professional, not necessarily because it was the best in their particular case, but because they were simply driven to it as a matter of self defense.

PROFESSOR JOHNSON. That is, the culture studies would not be chosen.

PROFESSOR KIDWELL. There are no culture studies.

PROFESSOR JOHNSON. If they were, they would not be chosen.

PROFESSOR KIDWELL said this was the point to which he was about to refer. Whether there would be difficulty in extending the system described to a course containing both culture and professional subjects, he would not venture to say offhand. He feared that, with the tendency to get through in the shortest possible time, it might be difficult to apply the elective system to liberal studies in connection with engineering studies. His impression was that the difficulty in arranging this was not greater than that which seemed to block the way when it was proposed to apply the system to their own courses. The faculty had, however, given no thought to this matter, because the college could not introduce the liberal studies even if so disposed, and because they wanted to bring up the preparatory instruction to so high a grade that there would be a sufficient degree of liberal training before the student entered the college. They felt there was no reason why an engineering college should not attempt to adopt the plan, now followed by law colleges and medical colleges, of limiting themselves purely to professional work.

It has been stated that the student can seldom or never know beforehand what he is to do after graduation. This is true, and it is well exemplified by graduates of the college where the speaker is engaged. If the student does not know, certainly the instructor does not; therefore no matter how carefully one lays out a fixed course, he certainly can have no reason to expect to hit the right thing better than can be done when a course is worked out for each man, for each year, based on all available information concerning the man himself. In the latter case one works more closely along the line of the student's personal equation, and one can certainly make a better selection in this way than if the work were laid out without reference to the man who is to execute it.

Professor Johnson thought he must be allowed to express a little surprise that so distinguished an authority on these subjects as Professor Greenhill, failed to recognize a very vital difference between what may be called a structural experiment and such experiments as the engineer makes. The engineer does not often build a full-sized machine as an experiment, in this country. What he might do abroad the speaker was unable to say. But here we do not experiment in that way. We make what are called specimen tests, and occasionally a model. The vital difference between the engineer and the mechanic is that the mechanic is obliged to get his facts from his full-size tests, and is unable to generalize, even after they are made, but must repeat his test on every new form of machine ; whereas the engineer gets his fundamental facts and his experience on which the machine is to be constructed, then he generalizes from these fundamental facts and conceptions, and thus he is able to design intelligently, so that his first machine is a success. That is what the speaker called engineering, and he would not consent to allow anything to be called engineering that is simply blind experimentation with full-size models and devices. That is the difference. If there were no such differences then there would be no engineering, as distinguished from the work of the mechanic. The man that made the first horseshoe was an engineer, but those that made them afterwards were mechanics. The mechanic follows along very closely, but the engineer must continue to solve new problems. If the engineer is not a man who can be safely trusted by the community to solve new problems safely, economically and successfully, then he is without a vocation.

THE CALCULUS FOR ENGINEERING STUDENTS.

BY F. W. McNAIR.

Professor of Mathematics and Physics, Michigan College of Mines,
Houghton, Michigan.

In the American colleges of engineering two extreme positions are occupied by instructors in the calculus. Each has its corresponding course and methods of instruction. One instructor takes the view that the calculus is studied to train the mind. He confines himself to niceties of demonstration, complex transformations, and applications to the geometry of higher curves. He teaches integration as merely the inverse of differentiation. In fine, he is devoted to strictly *pure* mathematics, and he seems to think, with the ancients, that the subject should not be degraded by being made to serve a useful purpose.

The student who finishes a course under this instructor turns to his more practical studies with no comprehension of how the calculus is to aid him. Often he has got the idea that, like chemistry or mineralogy, the calculus constitutes in itself a separate body of knowledge; and he does not even suspect that it is an instrument to be used in his further investigations.

A case in point is that of an engineer whose instruction was of the kind indicated. He says that the subject appealed to him strongly; he thought that he understood it, and his teacher concurred in this opinion. Yet a simple application made by his instructor in mechanics quite bewildered him. He could not realize that this fascinating study should have furnished him with means to solve mechanical problems. He is not alone in his experience.

At the opposite extreme is the instructor who sees only the fact that his students must *use* the calculus. His sole effort is to get at methods and results in the shortest possible time. He cares little for clearness, less for logic; and he has but a pitying smile for those teachers who waste time in endeavoring to establish accurate fundamental conceptions. He develops formula-users, not thinkers. His students get the idea that the calculus is a sort of automatic machine, in using which they have only to set the gears and push in the problem, when, in some occult way, the required answer will be turned out as the finished product. All goes well until in hydraulics, in electricity, or elsewhere, they meet a problem for which they have not the proper combination. Not being in command of the underlying principles, they are helpless.

There is no real antagonism between the purposes of these different instructors. It may be doubted whether good mental training can be given without imparting more or less of working knowledge. On the other hand, it is certain that an efficient working knowledge is not to be had by the man who does not know the basal principles, or who can not reason from them. The instructor who would do his work well, who would equip his students with an implement for actual use, must lose sight of neither purpose; and his methods must be a mean between the extremes above indicated.

To accomplish either end, there must be evolved in the mind of the student definite and accurate fundamental conceptions, and he must be required to reason logically from these to the processes to be established. One engineer says, " logically, if he has time." Most educators will agree that if there is not time to do the reasoning logically it is better not to attempt it at all.

The method by which the student is introduced to the study should be as time-saving as possible. For this as well as for other obvious reasons, it should, as far as may be, avoid giving him the notion that the calculus is radically different in its conceptions from anything he has studied before. He should not be led to believe that he has found a new department of knowledge in which the familiar laws of his previous study no longer hold ; rather, if possible, he should find the subject opening naturally out of the field already explored.

The writer's opinion, based on experience in the class-room, is that the development of the subject from a rate as its fundamental notion most perfectly accomplishes this end, since it starts with a conception already more or less familiar to the narrowest student, and permits him to form a perfectly clear-cut idea of the differential as a finite quantity.

The principal objection to the introduction by way of the theory of limits lies not at all in its logic, but in the fact that it permits the beginner no such definiteness of idea, presenting the differential only as an elusive variable whose limit is zero. In reality the method of rates and that of limits are metaphysically identical; and while that of rates certainly affords the easiest introduction to the study, the theory of limits steps in quite naturally as a powerful adjunct in deriving processes, in proving theorems, and in broadening the conception of the differential coefficient. Neither method is complete without the other.

Under the necessity for rigorous and independent thought, the infinitesimal method of introducing the calculus is, of course, barred. It is hard to understand how, on the plea of brevity and practicability, this method has been tolerated so long. Dying out it is, but it ought to be dead. It seems, indeed, absurd to have to say this of any method of instruction which requires the student to admit, nay, to assert, that while dx is not zero, the equations

$$dy = 2xdx + dx^2$$
$$dy = 2xdx$$

are at once simultaneous and exact; or which gravely tells the learner that the human mind is incapable of conceiving any reality corresponding to the terms "absolutely equal" and "zero"; that two quantities are absolutely equal when the difference between them is some difference smaller than any difference; that zero weight is some weight smaller than any weight. And when the phrase "in the limit" is added to gloss over the pretended reasoning built upon such conceptions, to delude the learner and perhaps the reasoner himself into the belief that the processs is as rigorous as that of limits, then is outrage done to the pupil's sense of logic.

Further, the instructor who tries this method will find that, compared with the use of limits, he loses rather than gains time, unless he is willing to ride rough-shod over the doubts and protests of his more thoughtful students. As a legitimate outcome of its use, these students get the idea that the results of the infinitesimal analysis are only approximations, sufficiently close, it may be, for ordinary purposes, but by no means rigorously exact; and they are often anxious to know how exact. There come to mind two instructors, in widely separated engineering schools, one of whom could not conceal his doubt either of the writer's sincerity or of his judgment in asserting the exactness of these results. The other, while not appearing to doubt the assertion, expressed his great surprise, and wanted to see how this exactness could be established. Of course neither had read widely, but both are thoughtful men and fair illustrations of the consequence naturally to be expected.

Sometimes a so-called method of infinitesimals is developed by means of the theory of limits, and this is used for introducing the student to the calculus. If rigorously established, this method becomes simply that of limits much abbreviated. In the class-room it will usually require more time than the direct method of limits, while it emphasises the great defect in that method.

In view of the fact that definite fundamental concepts are an all-essential requirement for genuine working knowledge, by far the larger part of the time and effort available for calculus should be spent in acquiring and fixing these elementary ideas and the processes immediately derived from them. Beyond these basal things, too much rather than too little is usually attempted, in both the number of topics and the extent of the treatment. It is safe to say that the consideration of those applications that the student will be called to make in his subsequent work in the school, will fill, if not over-crowd, the remaining time. Probably Maxima and Minima, Formulae for Expansion, Elements of Curve Tracing (including Tangents, Normals, and Asymptotes), Expression for Radius of Curvature, and the Process of Integration, are as much as can be undertaken in the average time with the average class.

For the engineering student, integration is chief among these subjects. The writer treats it along with the differential calculus, and rather as an application than as a separate branch of mathematics. He introduces it by first proposing several different problems, perhaps to find a specified hydrostatic pressure, the volume of a solid of revolution, and the work done against a varying force. In the attempt to solve each of these problems the differentiation is brought in (inversely, of course) as a means of reaching the result of the indicated summation. It is found that the student grasps the meaning and applicability of the process far more easily in this way than in any other. From this introduction to the end of the subject, problems in length of arc, area, volume, hydrostatic pressure, work, discharge, mean values, and so forth, should be frequently and incidentally given to illustrate the applications. It is a grave error to crowd the practical applications into a few recitations, and to treat them, usually about the last thing, as a topic entirely separate from the others, introducing here for the first time the idea of the integral as related to a sum, it having been previously regarded as merely the inverse of a differentiation. The writer is convinced that this error must bear a large portion of the responsibility for the difficulty engineering students meet in applying the process of integration to their later problems.

A process as far-reaching and as general as this one, must be contemplated for a considerable time, and under many different aspects before the mind can feel to any degree familiar with it. The necessary contemplation, as far as it can be brought about at all, can be induced only by repeated presentation of problems which compel the student to think his way again through the process. Moreover, the problems selected to illustrate integration, as, indeed, those to illustrate any other branch of the calculus, should be as really practical as it is possible to make them. It is all very well to figure out how far the fox ran on his curve of pursuit after the goose, provided nothing better offers in the field of the student's observation; but whenever possible the problem should have real meaning as applying obviously to something he either has done or expects to do. The practical problem not only teaches the use of the process, but the study appeals much more strongly to the student when he sees that he can do something with it, and he should be allowed to see this as soon and as often in his course as it can be done.

The treatment of integration has been thus fully written of, not alone because of its own importance, but because it represents fairly the writer's idea of the way in which the other topics should, as far as possible, be treated. Hardly too much stress can be laid on the advantage gained in preparing the way for a process by taking up, previous to its presentation, a problem in the solution of which the process is necessary. Certainly no one who has watched the satisfaction with which the student sees the evolution of the necessary steps, can doubt that this procedure at least adds interest to the calculus.

The investigation of maxima and minima, being next in importance to integration, should receive a full treatment for one variable, and perhaps its treatment for functions of more than one variable should be pointed out. Only a very elementary treatment of the other topics can be given under ordinary conditions, and if underlying notions are well looked after, probably this is all that is really necessary.

If the teacher is thoroughly in sympathy with the foregoing ideas, the text-book he uses is a minor matter. Right here, the writer wishes to protest against the dictum to the contrary, uttered at one of the earlier sessions of this Society by one of the foremost teachers of engineering in this country. Whatever the subject, whatever the text-book, it is impossible that the instruction, if any genuine instruction is given, should not partake largely of the teacher's individuality. Of no subject can it be correctly stated that "the text-book is of more importance than the teacher." Further, most educators will agree that the instructor whose ideal of his function in the class-room is no higher than "to keep order, to incite the laggards to activity, and to see that the students have understood the principles and solved the problems" is unworthy the name, much less the responsibility, of a teacher. The eminent Professor should have completed his anachronistic image by placing in its hand the birch rod or oaken ferule, thus gracing it, in the only way possible, with a scepter fitting the ideal it represents. The teacher, young or old, must remember that he alone is "responsible for the habits of thought and investigation" formed in his class-room by the student; and whether he would or not, this responsibility cannot be unloaded from his shoulders upon the text-book. It is to be regretted that there are in our technical schools so many teachers who, possessed of no higher ideal than the one mentioned above, would shirk this responsibility; who train the student to unquestioning acceptance of the statements of the book or of the instructor, in preference to putting forth the effort necessary to stimulate independent thinking. The work, or avoidance of work, of such instructors is a powerful factor in continuing the disrepute of technical education.

Withal, it remains that the text-book, though a subordinate consideration, is nevertheless an important one. Contrary, perhaps, to the natural inference from the foregoing part of this paper, the writer believes in a full text rather than an abbreviated one. The engineering student, perhaps more than any other, finds it profitable to carry his text-books with him when he goes into actual practice. The text-book in calculus, to be of lasting use, should cover a much wider range of topics than can be touched upon in the engineering class-room, and a considerably wider range than is covered by the books usually placed in the hands of the student. This does not mean that the book should be exhaustive on any one of these topics. Each should be introduced in as clear and as elementary a manner as possible, and so much of it should be treated as is sufficient for the purposes of the average student or engineer who may find need for it. This will mean, in general, that the treatment of those subjects studied in course will be carried further in the book than it is advisable to go in class. To the treatment of each subject should be added a full list of references to other works in which it may be pursued farther; and these, if necessary, should be annotated. The aim in making up the book should be to have it meet the requirements of the class-room, and at the same time to allow the engineer who has long since passed his student days, to readily and understandingly recover or supply a process. Because a given chain of reasoning appeals differently to different minds, there should be given, whenever it can be done, more than one demonstration or derivation for the same theorem or process, a geometric as well as an analytic, and so on. Practical applications should be clearly set forth, and concrete illustrations pointed out. This should be done especially clearly and fully in the treatment of those topics not likely to be studied in course. To all should be added lists of graded examples and problems, containing three to five times as many exercises as the student can solve in the allotted time. Among additions to the list of topics ordinarily treated in American texts the writer would include elements of differential equations, Fourier's series, hyperbolic functions, and approximate methods of integration, analytic, graphic, and mechanical. The last mentioned topic seems to be unreasonably slighted in existing books. It is worthy of full treatment, including the theory of one or more forms of mechanical integrators.

Whatever the methods of the book, great care should be taken to make sure that the student does not put the memorizing of processes in the place of the formation of clear-cut conceptions. He cannot be hammered too hard with the fact that processes will be forgotten; and when they are forgotten, only the man whose fundamental conceptions are sound can hope to restore them efficiently. A clear comprehension and firm grasp of the basal elements, obtained through proper contemplation and the requisite drill, afford the only surety against the young engineer's finding, in a very short space after graduation, that his calculus is but a hazy memory.

After all, this is but another way of saying that the real object before the instructor should be to teach, to compel, his students to think, clearly, logically, and independently. Only, in conformity with the utilitarian spirit of the age, the student must do this thinking about engineering matters, in preference to any others.

DISCUSSION.

PROFESSOR JOHNSON said that he thought all would agree with the sentiments expressed, that the conceptions of the calculus, both differential and integral, should be made both reasonable and concrete, giving a practical application at the time the theoretical work is first assigned, as far as possible. The description of the young man who became so flustered when he began to use the calculus in mechanics, applied exactly to the speaker's position when in college. On beginning the subject of mechanics the professor began to use the calculus, assuming, of course, that his students knew something of it. But the calculus had been taught them as pure mathematics, and integration as merely the reverse of differentiation, and it was all simply algebra. They had to go through the matter of maxima and minima, plane curves, etc., with no application to any practical problem. Hence it came that, for weeks after the speaker began the study of mechanics, he went to the class-room in a very nervous condition, realizing that he did not understand what the professor was putting on the board. He copied blindly. One of the most unsatisfactory parts of his course was the study of mechanics, where the calculus was employed continuously—in other words, the first application of the calculus to practical problems. He did not feel that he had any right to say how mathematics should be taught, but he did believe that it should be taught differently from the way in which it was taught to him; and he presumed that in fact there had been a great change in that regard. He had sometimes said that in the engineering colleges pure mathematics should be taught by engineers; that is to say, by men who had made practical applications of their mathematics. Such teachers would naturally and readily use illustrations of these mathematical processes that would commend themselves to the interest and comprehension of the young men. The speaker thought that we already have some teachers of mathematics who have studied, more or less, its applications to engineering problems. At the same time, there is always a tendency to draw teachers of mathematics from among those who have studied only pure mathematics, and studied it very deeply. This, he thought, is a mistake. At present, our teachers of mathematics are apt to be men who have taken long post-graduate courses in mathematics, and perhaps traveled abroad to continue their mathematical studies; but in nearly every case it has been a course of pure mathematics. It is a question whether teachers of mathematics in engineering schools should be selected from that class of men, rather than from those who have taken courses in applied mathematics of some sort (that is, some engineering course), but who are at the same time abundantly competent to teach the mathematical subjects. In the latter case they would usually be men who have studied little or no pure mathematics beyond that of the ordinary courses in engineering, including, of course, differential equations, but perhaps none of the so-called higher mathematics. The speaker wished to elicit the opinion on this subject of such men as the President, whom he regarded as abundantly able to judge of both sides of this question.

President Eddy replied that his solution of the question was an intermediate one. He felt that for engineering purposes, and perhaps for the best theoretical purposes, mathematical education in this country has not altogether pursued the best course, it having been too largely education in purely algebraical directions; and the men to whom we should look for filling the positions spoken of should be men whose principal interest in mathematics is in the direction of mechanics and mathematical physics, who would have an eye to the real and tangible objects for the purposes mentioned and would draw their illustrations from these things that are within the range, or closely by the range, of technical work. Such illustrations might not be strictly technical, but might deal with the forces of nature. The real mathematical training of those men would not be less than that of the so-called pure mathematicians of whom Professor Johnson spoke.

Professor Johnson asked whether we have any such men.

President Eddy replied that there are a good many of them. The field of mathematical physics is a very alluring one, and in this country, as before intimated by the speaker, too many of our young men have perhaps been turned away from that field; yet it is being cultivated, and such men are obtainable; if there were a demand for them there would be more of them; and he believed we ought to demand that sort of training for mathematical instructors in our technical colleges; he thought that a man should not be accepted for such a position if his only interest is elliptic functions and quantics and general mathematical theory, but that a man should be required whose interest in elliptic functions is to do with them what Professor Greenhill has done in his treatise, namely, to keep physical questions always in view; that his interest in electrical theory and in mechanics should be such as would keep physical realities in view. There is as great a field for mathematical theory in mechanics and physics as anywhere else; and a man could be a thorough mathematician on that side just as well as in the direction of quantics, etc., in which great and interesting discoveries have been made in recent years, but which are not useful at the present time in the engineering schools.

Professor Kidwell said that during his connection with the institution whence this paper came they had had three professors of mathematics; they were all different as to personal equation and previous training. The first had taken an excellent course, was highly recommended, and was certainly an able mathematician, yet neither the speaker nor any of his colleagues found this man's pupils satisfactorily trained for engineering studies. It had never dawned upon them that mathematics is other than a purely speculative study. The next man had been both student and professor in an institution widely different from that in which the first was educated. He was an adept in grinding his classes, and a drillmaster who faithfully compelled his students to go through all the mathematical evolutions prescribed by the text-book. His teaching was certainly good except in two vital points: there was not anywhere in it the spirit of practical application to the prosy realities of life, and he did not force his men to reason. He made them reflectors instead of originators of ideas. In consequence, they could differentiate and integrate without understanding the principles underlying these operations, and were helpless when required to make the most elementary applications to practical problems. Finally, when the author of the paper just read came in, it was the policy of the institution to require a large amount of engineering mechanics to be taught in connection with mathematics, and to limit the candidates to those who had had good training along that line in addition to pure mathematics. The results of this policy are excellent. The speaker would affirm without hesitation that during their first year in his own classes the pupils prepared by the author of this paper easily accomplished more than double the work the speaker had been able to get out of former classes, in other institutions as well as in the one with which he is now connected.

Professor Ordway said that he had had occasion to teach mechanical engineering, and that students had come to him who had gone through the calculus and whom the professor of mathematics regarded as being well trained, yet who seemed to be almost wholly ignorant of calculus. They could barely differentiate, but as for integration, they knew nothing of it.

Professor Tyler said that he had had something to do with the selection of mathematical teachers. As a rule, the Massachusetts Institute of Technology has not taken its own graduates, because it has had to depend upon them to so great a degree for other purposes, and it seem best to vary the stock a little. It seemed to the speaker that the best training for a mathematical teacher in an engineering college is to take an engineering course, perhaps in some other engineering college, and then to make a thorough, systematic study of more advanced mathematics. In the large engineering schools there are, he thought, always a few men who get the necessary command of the fundamental principles underlying engineering, who do not care to follow the engineering profession and are glad to teach mathematics. At the Institute there is almost every year a man, sometimes more than one, who continues his mathematical study further, and, perhaps, goes abroad for the purpose ; and when these men are available he believed them to be very good material.

President Eddy : You have exceptional facilities in that particular in so large an institution.

Professor Tyler added that he desired to express his appreciation of the protest against the characterization of qualities essential for a teacher of mathematics, as made at an earlier meeting.

Professor Sackett said that he thought that amongst all the use and abuse of courses, the calculus has suffered the most misuse. He agreed with those who think that the calculus is a means to a very important end, that of harmonizing with theoretical analysis the practical things that the advanced engineering student must meet. That is, the student should not in his mind divorce those common things he learns in physics from the analytical methods of deriving the same results. Every one has at some time met students who go through an analysis by means of the calculus and arrive at a result, forgetting entirely that it is in any wise allied to anything that they have ever heard or seen before, when in fact it may be a very common thing in physics—for instance, in the laws of falling bodies, which are a means of a simple introduction to calculus by the method of rates. It is important to use all such practical means as the calculus as far as possible, at the same time not making the calculus a repetition of that which has preceded it. Concerning formulas, of which something had previously been said in connection with another paper: the speaker did not believe in loading the student down with formulas in the calculus or in other mathematics. There are certain fundamental formulas that should be mastered, of course, but he believed it better to place emphasis upon the ability of the student to derive those that are necessary, until, by application, he learns those formulas, than to place stress upon the formulas themselves. He believed in leading the student through calculus, as far as is possible, rather than in driving him through. The student may forget symbols, but his training will remain with him.

Professor Bull stated that, as perhaps some present knew, he had been educated abroad. under such teachers as Schwartz, of Goettingen, formerly of Zurich, and Frobenius. He had had the same experience as that related by Professor Johnson. When he came to mechanics and was told to make applications he succeeded well enough, but he thought it was because he had taken two years for preparation, while in this country one year is taken. If applications that have practical value can be given in connection with the theory, it must be of advantage. It seemed to the speaker that there could be no question about that. Professor McNair, the author of the paper, had been a student of the speaker's and had some engineering training; but he never had any practical applications in engineering. He studied engineering mechanics, and mechanics as taught by an engineer; also descriptive geometry and some surveying, and the speaker had no doubt that this training had given him some advantage as a teacher in an engineering school. The speaker also mentioned that one of his teachers in mathematics in the University of Wisconsin was a man who had practiced engineering somewhat and had a great many interests in that line.

Professor Gray said that the discussion was very interesting to those who had been "through the mill," as Professor Johnson had been, a number of years ago. The speaker did not think there is so much difficulty now as formerly in regard to the difference between the professor of pure mathematics and the professor of applied mathematics. There is one difficulty in filling positions, and that is that the man who has studied applied mathematics prefers, as a rule, to teach applied mathematics. That is to say, he likes the applications more than the pure mathematics and prefers not to take a chair of pure mathematics. Such a chair as the one that had been spoken of a few minutes before, combining pure mathematics with its applications, is likely to attract a man better qualified to prepare students for the engineering courses than would be done by pure mathematics alone. The speaker thought that the schools in England, particularly Cambridge, are responsible for a good deal of the trouble that we have had in this respect. In the former days, when Cambridge was very prominent for pure mathematics, comparatively little of applied mathematics, even of physics, was taught; and such parts of mechanics as were taught consisted in the solution of problems, most of which were contrived for the purpose of making excellent illustrations of analytical manipulation rather than for imparting any mechanical ideas whatever. There has, however, been a change in that regard, and they are undoubtedly now in the foremost rank in bringing forward applications of the subject and teaching it in a practical way. If the teachers of engineering would lay a little of the blame to themselves and take some pains to be in sympathy with the professors of mathematics; if, instead of complaining that their students never get anything, they would, when they find that is the case, see that the professor of mathematics changes his course to suit theirs, there would result a great deal of benefit.

The speaker had himself had occasion in several cases to suggest changes in the teaching of mathematics, and he had never found any difficulty whatever; he had never found that the professor of mathematics was in any way inclined to resent a suggestion, but rather that he welcomed the advice which the speaker was inclined to give as to the improvement of the course, not perhaps as a course of mathematics, but as a course to suit the policy of his colleagues, the teachers of engineering.

Professor Allen remarked that what Professor Gray had said had reminded him of a point that had come to his mind frequently of late, and this was that the teacher of engineering is often inclined to find that the man who preceded him failed to bring the students up to the standard that he desired. This is not altogether the fault of the teacher of engineering; it certainly is not the fault of the teacher of mathematics, and the speaker did not know that it is the fault of the student. Perhaps it might be put in this way—that it is the fault of human nature. One must not expect too much of the student. It is very largely true that any subject studied in the first instance becomes a thing of the past when the student has progressed a little further, and it does not settle down as fully into a part of himself as happens when, at a later date, an application is made of it. The speaker did not believe it possible to secure through the teacher of mathematics, or through the teacher who first brings a subject to the student's attention, the results that are desired. It is the second attack that makes the more permanent impression, and part of the difficulty that has been experienced is due to the fact that we have failed to take this truth into account. Students generally came to the speaker not so well prepared as it seems that they ought to be; he knew that they went to other professors not so well prepared in certain subjects as it seemed they ought to be. In one case in the speaker's work, on some simple point which was purely an application of principles upon which they had received an exceptionally thorough drill at the hands of another professor, they seemed to be all at sea. The difficulty lies, to a considerable extent, in the human nature of the student; and the speaker thought we sometimes fail to take that sufficiently into account, and are prone to expect more from the student than the actual circumstances warrant us in expecting.

Professor Ostrander said his views coincided with those expressed by Professor Allen. In the school that is entirely technical, it is of course very desirable to have mechanics taught with reference to engineering; but there are many institutions in which the course in mechanics must be general. He had found it very satisfactory to devote perhaps a week to a review of mathematics before taking up mechanics; and he found that students who had a general training, without any special reference to the subjects of mechanics and engineering, very readily comprehend the applications taken up. He thought that a little time spent in that way in the beginning of a course, perhaps outside of the subject directly in hand, would save a great deal of time further along in the course.

THE INFLUENCE OF SCIENTIFIC RESEARCH UPON THE DEVELOPMENT OF CHEMICAL TECHNOLOGY.

BY DR. H. BUNTE.

Professor of Chemical Technology in the Technical High School, Karlsruhe,
Germany.

In an age when the brilliant discoveries of natural science are sufficient to amaze all classes, when the state recognizes the fostering of the sciences as one of its principal duties, and makes special appropriations in their behalf, it may seem almost superfluous to dwell upon the importance of scientific work to the intellectual and material development of the world. However, although in general there is no doubt among educated people as to the importance of scientific work, in a few individual cases the relation between scientific and economic life is not so obvious that it is clearly understood by the common people.

In this respect chemistry finds itself in an unfavorable position. While the masterpieces of the architect, of the engineer, of the machinist, and of the electrician compel acknowledgement of the creative ability of their authors and of the tremendous influence of technical science on all the relations of life, no cause for remark is seen in the creations of the chemist. Whether the brilliant colors come from plants or are synthesized in the laboratory, whether sugar is taken from the tropical cane or from the domestic beet-root, whether the medicaments or perfumes of costly herbs are formed by the radiant energy of the sun or by the art of the chemist, remains, as a rule, completely hidden from the masses. Even where the agency of the chemist is recognized, it is most often to his disadvantage, and, as if some of the diabolical art of the alchemist still clung to his profession, he is condemned as a plagiarist from nature, as a falsifier and a destroyer.

In order to judge correctly the importance of chemistry among the factors which determine our civilization, allow me to glance over the history of its development. I will endeavor to show, in a few typical examples, the mutual relation between scientific research and chemical technology, in order to prove that through their combined influence the chemical industry, especially in Germany, was raised to the prominent position it to-day occupies.

Until the middle of the past century, chemistry resembled a traveller, who, in a dense fog, struggles through a rich, beautiful region. Allured by the phantom of "the philosopher's stone," which promised immense riches, and "the elixir of life," which was said to heal all diseases and to renew mind and body, it strayed away on labyrinthine paths, as if led by an evil genius. But, on the way, rich treasures of experience were collected, and these were handed down from generation to generation in interminable receipts. But a steady purpose, a well-defined plan, a single bond to unite all these facts, is hardly to be found; only through such a product of the imagination as the "phlogiston" theory was an attempt made to correlate the observed phenomena.

Then, in the second half of the eighteenth century, the fog lifted, the sun shone through, and scientific chemistry became visible to the world. With a sudden impulse, the clear light of day spread over the most important phenomena of daily life, such as the phenomena of combustion and of respiration, which previously had been enveloped in a mysterious darkness ; and the confused mass of observations became an orderly system.

At the head of those noble minds that raised chemistry into the circle of the sciences, towers Lavoisier. Men like Berthollet, Guyton, Fourcroy, Chaptal, and the mathematicians Monge and La Place, alike distinguished for their scientific knowledge and for their broad comprehension of the problems of the age, worked with the great genius, Lavoisier, and stamped the new departure of chemistry as a French science.

Seldom has a young science been able to prove more conclusively its beneficent influence on the promotion of intellectual and material welfare than did chemistry in the first years of its scientific life.

Among the industries which, toward the close of the last century, made remarkable progress, are to be noted in particular spinning and weaving, which began to make use of the foreign as well as the domestic cotton. The mechanical part of the manufacture of woven goods had already made great progress, but the chemical part, the bleaching and the dyeing, was still performed according to old methods. The primitive practice of spreading the cloth on a grass-plot and thus subjecting it to the action of the atmosphere, which required from two to three months and which cost almost as much as the manufacture of the goods from the raw fiber, was used exclusively in bleaching cloth. Berthollet, who in 1784 was appointed inspector of dyeing, recognized that the bleaching properties of chlorin, an element which had just been discovered by Scheele, might be valuable in the textile industries; and he proposed a method of bleaching by chlorin, which yielded finer goods in a few hours than were produced by the old lawn-bleach in as many weeks. It may be truthfully stated that only since the introduction of chemical bleaching has the manufacture of cheap cloth on a large scale been made possible. James Watt studied Berthollet's process in Paris, carried it over to England, and laid thereby the foundation of a great development of chemical activity in his native land.

In the field of dyeing, the efforts of Chaptal, the chemist of the Gobelin carpet manufactory in Paris, succeded in making universal throughout France the use of the turkey-red or madder style of dyeing, which later, especially in Alsace, reached a high degree of perfection.

In bleaching and dyeing, the treatment of the cloth with lye, soda, and soap is of the utmost importance. With the extension of the textile industry, the demand for the natural soda, the so-called "barilla," for which vast sums went to Spain yearly, increased so rapidly that the Academy at Paris offered a prize for a feasible method of making soda artificially. After chemistry had recognized in 1736 that the alkaline base of soda is contained in rock-salt, the latter naturally became the raw material for the manufacture of soda; and in 1787 LeBlanc, a colleague of Berthollet, proposed a process, which for almost a hundred years has been the pole-star to the wholesale chemical industry, and which even to-day occupies an important place.

Not long, however, could chemistry devote itself to the solution of such peaceful problems. The excesses of the French Revolution threatened the very basis of civilization, and one of the first victims of the Reign of Terror was Lavoisier, the founder of modern chemistry, who, as a tax collector, ended his days under the guillotine. Useless were the attempts made to save for scientific work the life of the great investigator, by urging the inestimable value of his services; with the words, "Nous n'avons plus besoin de savants" the petition for mercy was refused.

The ignorance and self-destruction betrayed in this sentence soon made itself felt. The convention at Paris had by 1793 involved France in a bitter conflict with almost all the states of Europe, and had brought her to the brink of ruin. A large army had been assembled, but the magazines were empty, and not one tenth of the necessary materials of war, which formerly were for the most part imported, could be provided. No cannon, no muskets, no munitions; and for the manufacture of these articles, so necessary in the prosecution of the war, there were in France not even the beginnings of an industry. The arts of the manufacture of steel and of fire-arms had for centuries been confined exclusively to Germany and England; and in the making of gunpowder, Indian saltpeter was used. Cut off from all supplies, the government had to search out and press into service new sources. Raw materials, which formerly had been supplied by trade, had to be found in France; methods of manufacture had to be devised and developed in the shortest possible time into industries capable of standing the most excessive drains. The theoretical methods of manufacture and the old processes which even after years promised only partial success, could in this case afford no assistance; only exceptional knowledge and ability could find a way of safety. The Committee of Public Safety made a most urgent appeal to science; and the most prominent scholars came together to consult.

The most difficult problem, which, according to the memoirs of Arago, instantly agitated the chemists, was the manufacture of gunpowder. Where in the world are we to obtain niter, was the great and oppressive question. "From our own soil," replied Monge: "the stables, the cellars, and the vaults contain more saltpeter than people realize." And relying boldly on this inexhaustible source, which stood ready to the hand of genius, and glowing with patriotism, Monge cried out, "Give us earth containing niter, and in three days all our cannon shall be loaded." As a result, at once, from one end of the republic to the other, people began to dig up the ground around their stables, and to dissolve out the precious saltpeter. Chemistry invented new methods of rapid purification and drying, and it was found that the demand for niter for the manufacture of gunpowder could be abundantly supplied. In nine months twelve million pounds of niter had been recovered. The chemists Berthollet, Fourcroy, Vauquelin, and Chaptal superintended and improved the manufacture of gunpowder; Monge, who with Berthollet and Vandermonde had extensively investigated the constitution of iron and steel, organized the manufacture of fire-arms, erected all over the country gun foundries and musket manufactories, and taught workmen to make side arms from the newly produced French steel. After the most pressing needs were provided for, new means of defense were devised, the optical telegraph was invented, and balloon ascensions became a part of the art of war.

The spirit which in so short a time had achieved such glorious successes, accompanied the soldiers to the field of battle, and brought victory to the arms of the republic.

With irresistible power these events inculcated the doctrine that science, which had been treated so contemptuously, was necessary to the preservation of the state; the rulers of the Republic were obliged to yield this point. In the beginning of the year Three of the Republic (September, 1794) the "Academy of Paris," which had been abolished as a royal institution, was reëstablished and expanded to the "Institut National de France," and the "École Polytechnique" was founded—two immortal institutions, which shine forth for all time as bright spots in the gloomy history of the Reign of Terror.

The men who had performed such conspicuous service for the country in its time of peril were retained after the establishment of law and order, as the counsellors and leaders in the organization of the system of education which was adopted at once. The knowledge which had enabled Berthollet, Monge, Fourcroy and Chaptal to perform such astonishing services, was to become the possession of all educated people. Accordingly, preference was given to the so-called realistic education, based on science and mathematics, oftentimes to the exclusion of the other branches of instruction. And this tendency, unlike many of the institutions of the republic, was not of transient duration, but became more and more firmly established, when, beginning with 1795, men whose very creed was realistic education were appointed to manage the internal affairs of the state, and to regulate the system of instruction. In 1801 the chemist Fourcroy, who, with Monge, was prominently concerned in the founding of the "École Polytechnique," drew up, as minister of instruction and at the instance of Napoleon, a plan for a system of public schools. The management of all the internal affairs of the state was intrusted to the chemist Chaptal and the mathematician Laplace. The respect which science enjoyed appears in the way in which Napoleon, before his Egyptian campaign, signed his proclamations from Toulon, Malta, and Alexandria "Bonaparte, Fellow of the National Institute and Commander-in-chief." The change in the form of government did not in the least alter the already deeply rooted principles governing the system of instruction; and the realistic education spread outward from France over all the neighboring countries with more or less prominent results.

One result of this movement was the founding of "Polytechnische Schulen" in Austria and Germany, which were named after the Parisian school, but which differed radically from it in their organization. The first of these schools to be founded within the limits of the present German empire was the Karlsruhe Polytechnical School, which was established October 7, 1825, under Grand Duke Louis.

While the events described were taking place in France, at the end of the last century, gloomy political relations burdened the German fatherland and crippled scientific endeavors and aspirations. This was shown in the attempt to introduce into Prussia the manufacture of sugar from the beet. About the middle of the previous century the chemist Marggraf, of Berlin, had observed that sugar, which was obtained in the English colonies from the sugar-cane, is also contained in considerable quantities in the domestic beet; and he had pointed out the economic significance of this fact. In 1799, Achard, his pupil and successor in the Berlin Academy, laid a memorial before King Frederick William III., in which he proved that the sugar consumed in the kingdom, which was not inconsiderable, could be amply supplied by the beet; and he asked the support of the state in his undertaking. After he demonstrated the utility of his process, Achard received an advance of 50,000 thalers, to start, on the estate at Cunern, the cultivation of the beet and the manufacture of sugar. In 1802, the factory went into operation, but there were numerous technical difficulties to be overcome, and ultimately, during the wars, the establishment was destroyed by fire. Encouraged by the example of the state, several private capitalists had established beet sugar manufactories, which prospered under the protection of the continental blockade of November 21, 1806, which completely excluded colonial sugar; but when, with the fall of Napoleon in 1814, this protection was withdrawn, the sugar industry in Germany, after this brief existence, became extinct.

Affairs assumed an entirely different aspect in France. As soon as Napoleon received intelligence of the attempt to extract sugar from the beet-root in Germany, he recognized the importance of this industry to the economic development of his own country, especially during its war with England. Under the spell of his great power, a vigorous beet-sugar industry arose in France. At his command five factories were erected as professional schools and named by a hundred students of medicine, pharmacy, and chemistry; the ministry had one hundred thousand acres planted with beets, and every factory which produced over ten thousand kilos of sugar yearly was exempted from taxation for four years; four larger factories, with a total yearly output of two million kilos, were erected at the expense of the state, and still another at the expense of the Emperor. And so it happened that the beet-sugar industry, which originated in Germany, first attained technical importance in France. After the fall of Napoleon and the raising of the continental blockade, a decline ensued; but the technical process had meanwhile developed sufficiently to compete with the colonial sugar, and under the protection of a duty the sugar industry quickly recovered.

But after several decades Germany has overtaken

France, and in the last few years, far surpassed her in the production of sugar. At present, from four hundred German factories, the output of sugar is one and one half billion kilos yearly—more than double the production of France. The direction of the sugar trade has been reversed; while formerly the Old World was supplied with sugar exclusively from the English colonies, to-day about two thirds of our own sugar, one billion kilos yearly, goes from Germany to England and to America, and the German sugar rules the markets of the world.

The immense sums which through this industry go to agriculture, to the mechanic arts, to trade, and especially to labor, are hardly to be expressed in mere figures; the tax on sugar alone nets the German empire over eighty million marks yearly, or one and six tenths marks per capita.

Before tracing further the development of the chemical industry in Germany, permit me to speak briefly of England, whose trade and manufactures developed rapidly, of necessity, during the continental wars. With the textile industry, the manufacture of sulphuric acid, soda, soap, chlorin, and bleaching-powder received astrong stimulus; and there also arose a new industry, the manufacture of illuminating gas.

The progress in mechanical technology had completely changed the methods of spinning and weaving, and had replaced manual labor with mechanical appliances. The desire to increase the hours of the working day, and by means of artificial light, to be independent of the change of day and night, gathered strength yearly. The means of illumination then known were extremely unsatisfactory. Said Goethe, "I know of no more acceptable invention than a light which would burn without snuffers." In these words he expressed the intense longing of his age for better means of illumination, which was satisfied by the discovery of coal gas.

It is no accident that the two great discoveries which were to influence most profoundly the exterior form of society, the perfection of the steam engine and the manufacture of illuminating gas, came into the world from the same place. James Watt, the father of the modern steam engine, and William Murdock, the discoverer of illuminating gas, worked together; and from their factory in Soho came improved steam engines and the first contrivances for the manufacture of coal gas, to be used by the spinning and weaving industries of England.

Even the boldest mind did not yet venture to think of providing entire cities with illuminating gas, for but a short time had elapsed since Lavoisier devised a modern gas holder for storing the gas, and gun-barrels screwed together were still used to deliver the gas. To-day, by means of hundreds of kilometers of piping, we are accustomed to provide our modern cities with gas, even in the most isolated streets; and we see nothing remarkable in the fact that we have at our disposal the means of replacing darkness with light whenever and wherever we please.

I do not need to dwell upon the revolutions which, in the course of years, this advance in methods of lighting has occasioned in industrial fields, in our public and private life, and in our entire social intercourse. As a typical example it may be cited that the Council of State in the time of Louis XIV. met at seven o'clock in the morning in order not to be disturbed by the fall of darkness, while now the English Parliament transacts the greater part of its affairs with the aid of artificial light.

Ten years after the War of Liberation, the study of chemistry revived in Germany. In 1824, Liebig, at the age of twenty-one, after studying at Bonn and Erlangen, and having perfected his education at Paris, ascended the chair at Giessen. At that time there was in the German universities no opportunity for independent chemical research, and there were no technical high schools. Liebig recognized that it was necessary to combine laboratory instruction and practice with the explanations of the methods of chemical investigation and research, which he delivered in his lectures. He accordingly erected working desks for his scholars in the lecture-room, and thus, in 1825, originated the first system of laboratory instruction—an entirely unique departure, which increased in utility and success. Under the eyes of the master the young chemists became familiar with the methods of analysis and took an active part in his researches.

The investigations of Liebig were by preference confined to the province of organic chemistry. The synthesis of urea by Wöhler in 1828 had given a fresh impulse to the study of this branch of chemistry; for it was proven that an important product of the animal economy could be artificially prepared in the laboratory from inorganic sources. With this discovery the barrier, that appeared to separate organic from inorganic chemistry was removed, the belief that the chemical transformations of the plant and animal kingdom were due to a particular vital force was disproved, and the entrance to the domains of plant and animal physiology, to agriculture and pharmacy, was opened to chemical research. In 1840, Leibig collected the labors of the school at Giessen, which was principally engaged in this new field of chemistry, in his monumental work, "Chemistry, and its Application to Agriculture and Physiology." In this book he proved, on the grounds of the most exact scientific investigations of the component parts of the ashes of plants, that the growth of vegetation and the yield in plant culture were primarily dependent on the presence in the soil of certain constituents, such as phosphoric acid, potash, and nitrogen. He then proceeded to develop a new theory of fertilization, which appeared to contradict the experience of a thousand years of husbandry. Among practical agriculturists his views met with the most violent opposition. In defending their theories, Liebig and his associates developed an astonishing polemical ability.

"Natural philosophy has this peculiarity, that its revelations are just as obvious and intelligible to the sound mind of the common people, as to the educated; the only advantage the latter possess is that they have a knowledge of the means by which these have been reached." Starting with this proposition Liebig wrote his "Chemical Letters," now classics in form and matter, which were destined to make chemistry intelligible to educated people and to open the way to new ideas. At first, as was to be expected, the new doctrine in some respects was deficient and even productive of error; but the deficiencies were covered and the errors eliminated, so that with increasing distinctness facts supported the correctness of Liebig's principle; and to-day agriculture finds in his theory its most potent weapon in meeting the crushing foreign competition and in increasing the production of the home land.

The new theory of fertilizing found its first adherents in England. Gradually it gained followers in Germany, where the beet-root culture, which Liebig at first pronounced a temporary undertaking, had met with the most brilliant practical success, and where, in consequence, other agricultural enterprises were established.

It is hardly necessary to describe the influence which chemistry, following in the foot-steps of its great pioneer, has exercised on agriculture; the hundreds of experiment stations, which, starting at Giessen, have spread all over the country, testify to the great revolution which has been completed in the course of a single generation. I have time only to consider the effect of Liebig's new theory of fertilizing on the chemical industries.

Most conspicuous is the success realized in the application of phosphates for artificial manuring. The phosphates, in accordance with Liebig's suggestion, were treated with sulphuric acid and changed into superphosphates. At that time, phosphates were derived entirely from bones; this source was soon exhausted, and chemists began to seek out mineral phosphates. In the course of the next ten years, large deposits of phosphates were discovered on the Lahn in Germany, on the Somme in France, in Estremadura in Spain, in North Carolina and Georgia in the United States, and in Tunis in Africa; and these deposits were worked in the interest of agriculture. In 1856, the first factory for the manufacture of superphosphates of lime was erected in Germany. To-day mineral phosphates are brought to us from all parts of the world, and we consume yearly about five hundred million kilos.

For a fertilizer containing potassium, unexpected treasures were found, early in the sixties, in the salt strata above the Stassfurt rock-salt deposit, which hitherto had been considered as worthless. The yearly production at Stassfurt, from which Germany not only supplies its own wants but furnishes potash salts to the rest of the world, amounts to over two hundred million kilos, valued at twenty-four million marks.

The sources available in Germany to satisfy the demand of agriculture for a fertilizer containing nitrogen were very unsatisfactory; the sulphate of ammonium obtained from the ammoniacal liquor of the gas-house could not begin to supply the demand, and so for decades millions of marks yearly were sent to England in payment for salts containing nitrogen. Only recently has it been attempted with considerable success to utilize the nitrogen of prehistoric plants as contained in coal, by saving the products of distillation in the manufacture of coke; and this industry bids fair to supply German agriculture abundantly with nitrogen.

Besides ammonia, another salt, Chili niter, which contains nitrogen in the form of nitric acid, has attained considerable importance in German husbandry. Alexander von Humboldt, in his travels, brought back to Europe from the islands of the Pacific some samples of guano; through the influence of Liebig's doctrine, these distant islands became the rendezvous of mercantile armadas, which transported the valuable manure to the Old World. But the supply of bird excrement, which at first had been considered boundless, was nearly exhausted in the early seventies, and the merchants turned for trade to the less favorably located deposits of saltpeter at Tarapaca, in the interior of the continent, where a few enterprising Chilians had commenced mining operations. The Peruvian government, which in the exhaustion of the guano beds saw itself deprived of its most prolific source of revenue, drove away the Chilians in order to take possession of the saltpeter beds, and thereby kindled a war between the two republics in 1880, the so-called Saltpeter War, which resulted in a complete victory for Chili. The salt, now called Chili niter, has been shipped to Europe since then in immense quantities—one million tons in 1894, worth one hundred and forty million marks, of which about one third, worth forty million marks was unloaded at Hamburg, and used for the most part on German farms as a fertilizer.

Thus, in this instance, as in many others, events proved that the interests of the chemical industry, of agriculture, of international trade, and of politics are most intimately connected.

While Liebig, in the fifties, was yet striving with the practical agriculturists for recognition of his new theory, and was supported by a number of enthusiastic adherents, another group of his scholars, at whose head stand A. W. Hofmann and Kekule, extended the scientific structure of organic chemistry. The examination of coal tar, which was obtained in increasing quantities as a troublesome bye-product in the manufacture of coal gas, was undertaken with special interest. Chemists had already found that benzene and artificial oil of bitter almonds could be obtained from it, had discovered, among other important substances, anilin, a compound very similar in its properties to indigo, and had recognized that, when properly treated, it possessed especial efficiency in affording colored compounds. When in 1859 Verguin, at Lyons, discovered that brilliant color-effects that astonished the entire world could be produced on silk by using anilin, chemists threw themselves feverishly into this new field. Dyestuff after dyestuff was discovered, until manufacturers were able to make from anilin all the colors of the rainbow. In England and France, where the coal tar dyeing industry first developed, dozens of patents for dyeing with anilin were taken out; only toward the end of the fifties was the industry transferred to Germany, where it found favorable soil. The manufacture of these artificial colors required a new technical process, which adapted to the arts the methods practised in the laboratory; with the increasing scope of the business, new factories on a gigantic scale were erected, which pressed into service the most modern instruments of the mechanic arts and of the most advanced technological science. And right here was demonstrated the great superiority of the German school, which included in its staff chemists that were as thoroughly practical as scientific, and that had remained in close touch with all the advances in the domain of the natural sciences.

No branch of chemical activity shows more clearly than the coal tar industry the brilliant successes that arise from a combination of scientific research with practical experience ; in no period has scientific chemistry enjoyed greater triumphs, or technology reaped richer rewards. With astonishing rapidity, new observations and methods have been utilized practically ; and technology, in addition to furnishing scientific investigation with a number of fruitful suggestions, has assisted it through the agency of large work-shops and laboratories.

Heinrich Caro, who was one of the prominent pioneers in the brilliant development of the chemistry and the manufacture of artificial colors which has taken place in the last thirty years, and who embodies the scientific tendency of chemical technology, has described before a circle of his colleagues this great transformation.* I regret that I must deny myself the pleasure of initiating you, at the hand of this great leader, more deeply into this field of chemical research ; a few hasty remarks must suffice.

Ten years after the manufacture of the anilin dyes had begun and had attained such perfection, Graebe and Lieberman succeded in synthesizing alizarin, the important permanent red dyestuff of the madder plant, from anthracene, a constituent of coal tar that had previously been known to only a few chemists. At this time (1868), large tracts of land were employed in the south of France and in the Levant in the cultivation of the madder-root. The value of the finished dyestuff was about seventy million marks yearly. Hardly ten years later, hundreds of tons of anthracene were extracted from coal tar and transformed in chemical factories into alizarin. The chemical product was both purer and cheaper than the natural product. The victory over the natural dyestuff was complete; the madder industry was destroyed. The methods of dyeing with turkey-red were simplified, and the pure and beautiful artificial dyestuffs were used on a scale much greater than was at first expected. To-day, after less than twenty-five years, the German factories produce almost four fifths of the alizarin used in the world, the yearly exports being worth twenty-five million marks.

---

* *H. Caro*, Die Entwickelung der Theerfarbenindustrie. Berichte der D. Chem. Gesellschaft, 1891.

The manufacture of artificial alizarin was followed in the next ten years by the discovery of a number of important groups of dyestuffs whose members are numbered by thousands. On account of their brilliancy, their easy application, and their purity, they have slowly but surely crowded the natural dyestuffs out of the market. In 1879, Baeyer, in Munich, succeeded in synthesizing indigo, next to alizarin the most important dyestuff, as the final consummation of a long series of scientific investigations, through which chemistry has been enriched by a host of new facts and processes. Hand in hand with the discovery of new dyestuffs goes the endeavor to extend the practical application of the same, and to simplify the methods of dyeing. The dyeing and printing industries have been completely revolutionized in the last ten years, and the brilliant colors and the matchless cheapness of colored and printed goods prove to the common people the beneficent influence of chemistry on the development of these industries.

Less noticeable, although hardly less important, are the successes that the combined skill of scientific investigation and chemical technology have achieved in the preparation of pharmaceutical products. The artificial manufacture of the most important drug, quinine, has not yet been accomplished; but happily this is not true of the other alkaloids; and a long list of substances, very similar to quinine in their properties, such as antipyrin, antifebrin, and phenacetin, for which we must thank chemical synthesis, are to be found in the medicine chest.

The laboratory has also produced a number of compounds such as the narcotics, the opiates, and the hypnotics, also saccharine and dulcin, substances a hundred times sweeter than sugar, of such astonishing properties that in the previous centuries it would have been thought that they could be manufactured only with the help of the Evil One. To these must be added the antiseptics, the disinfectants and sterilizing agents, which promise in the near future a glorious triumph over devastating epidemics.

If, in addition, we include the artificial preparation of perfumes like musk, and the manufacture of the salts used in photography, we have another branch of chemical industry that is daily extending its scope, and that in Germany furnishes with employment dozens of factories and thousands of workmen.

Scientific research has completely revolutionized the industry in explosives and the allied branches. Until within a few decades the miner and the engineer used the black powder, made from saltpeter, sulphur, and charcoal, that was also used in the prosecution of war. Chemistry recognized the rending power of nitro-glycerin and of gun cotton, but until the fearful forces of these dangerous substances could be confined, they were incapable of technical application. In 1867 Nobel mixed nitro-glycerin with infusorial earth, and succeeded in changing it into a relatively safe substance. Since then dynamite and blasting gelatine have performed priceless services for the engineer and the miner.

When modern military science proposed to do away with the smoke from powder and to increase the range of fire-arms, chemistry transformed gun cotton and nitro-glycerin, which resolve into invisible gases, into explosives adapted to the purpose, and thus by means of smokeless powder completely changed the methods of warfare.

The transformations that, under the influence of chemical research, have taken place in the field of metallurgy, are hardly less important. Iron, the metal which has most profoundly influenced the development of civilization, has in phosphorus, which makes it useless for many purposes, its most dangerous enemy. Before it was found possible to render harmless the phosphorus contained in the German iron ores, the domestic iron industry was in a crippled condition, for the blast-furnaces had to look to Spain and Sweden for their iron ore; but after 1878, when the Thomas process made it possible to slag off the phosphorus, our inexhaustible deposits of iron ore proved their value, and the German iron industry gained with gigantic strides on its more favored rival on the opposite side of the Channel. The injurious phosphorus is simultaneously transformed into a valuable fertilizer, and the German blast-furnaces' Thomas-dust supplies agriculture with about fifty million kilos of phosphoric acid yearly, to be used in fertilizing fields and meadows.

A few years ago, when, in the Transvaal, the old method of amalgamation, by means of which only a part of the gold contained in the ore was extracted, was found to be unsatisfactory, chemistry embraced with considerable success the old trade of the alchemist. By means of a dilute solution of potassium cyanide, the tailings, which had previously been thrown away as valueless, were thoroughly lixiviated, and hundreds of millions of marks in gold were saved.

What chemistry can perform when coupled with rapidly developing electricity, is not yet a subject for retrospection. The aluminium industry, the preparation of metallic sodium, the manufacture of acetylene from calcium carbide, and the manufacture of the diamond-like carborundum, are promising beginnings. At present, under the influence of electrochemistry, a revolution seems to be taking place in the alkali and the chlorin industries.

Wherever we may look on the wide field of chemical enterprise, we see active life and systematic progress. For years the methods of scientific research have left the laboratory of the savant and have been domesticated in the factories of technology. With this "philosopher's stone," chemistry has discovered how to acquire riches by changing valueless products of nature into valuable commodities. Day by day, chemistry in all its branches permeates more deeply our industrial body, influences more profoundly our public and private existence, and surrounds ever more closely, as with an invisible net, our entire modern civilization.

It is evident that the prosperity and progress of so widely diversified a professional pursuit are influenced by a number of circumstances, which are intimately connected with technical development. Carefully regulated legal relations, an intelligent government, and a sound state, are indispensible to the development of every industrial enterprise.

With the reëstablishment of the German Empire, German technology entered the period of its most vigorous growth; and while England and France ruled the field until the middle of this century, within the last quarter of a century the German chemical industry has overtaken its older rivals, and has surpassed them in most lines.

The extent of the chemical industry in Germany may be gathered from the following statistics. In 5,800 enterprises, more than 100,000 workmen are employed, with a pay roll of about one hundred million marks. With regard to the value of the output, information can be obtained only from our trade with foreign countries. The part taken by the chemical industry in international trade in 1895 was valued at five hundred and seventy-two million marks, about ten per cent. of the total trade of Germany; the imports. valued at two hundred and seventy-two million marks, consisted principally of raw materials, such as Chili saltpeter and pyrite; the exports, valued at three hundred million marks, were almost entirely manufactured articles, coal tar dyes, explosives, and other chemical and pharmaceutical products. The great economic importance of these industries, which for the most part are carried on in isolated factories, far from the public gaze, may be gathered from these figures.

Not only at this material prosperity may the chemical industry of Germany glance with satisfaction, but it may also look with pride upon the part it has played in legalizing the ethical demands of the time. Convinced that the maintenance of a contented and devoted working-class is the primary requisite of technical and economic success, our great chemical industries have combined to secure social legislation for the protection of the workman from the dangers of his calling, for the prevention of disease, and for securing re-employment to the workman recovering from illness, which is to be sought for in vain among similar business enterprises in foreign lands.

If as chemists we look with pride at this gratifying development, as teachers there should be mingled with this feeling a sense of grave responsibility, in consideration of the task which devolves on us of educating the rising generation. and of preparing the champions who in the peaceful struggle of the nations are to maintain our industries in the position of preeminence which they to-day occupy. With every day the sphere of chemical enterprise widens, so that it is no longer possible for a single individual to understand the entire subject. Even if we should succeed in imparting to our students all the treasures of experience, an oppressive store of facts and phenomena, we should be obliged to own our success fruitless; for nowhere does a revolution take place more rapidly than in the domain of technical and scientific chemistry. A method that to-day is considered practicable is abandoned to-morrow, a highly prized product is replaced by a better one.

Only education in methodical scientific research in the systematic pursuit of an object, based on a thorough knowledge of his profession, can enable the young technicist to adapt himself to established enterprises, to take an active part in their advances, and to remain always at the head of his profession. Nowhere does the old proverb "Inaction is recession" find a more striking verification than in the field of technology.

CHEMICAL ENGINEERING.

BY JOHN M. ORDWAY.

Professor of Applied Chemistry, Acting Professor of Civil Engineering,
Tulane University, New Orleans, La.

Engineering is the designing and carrying out of large constructions or operations requiring more than ordinary skill and calculation. The word is ultimately derived from the Latin *ingenium*, which means inborn talent, genius, or ingenuity—something that enables the possessor to originate instead of merely imitating the plans of others. But this profession calls for stern discipline of mind as well as for natural gifts. There are artisans, machinists, millwrights, surveyors, and so-called inventors, that can do what they have seen done, and can elaborate and improve details, but who lack the power of deduction from general laws, the power of selection and co-ordination, which enables the true engineer to accomplish great results with the least expenditure of force. One may be a very good captain of a company and yet quite unfit to command a brigade. Still it must be allowed that observation and reflection have often much enlarged minds of good natural calibre, and so we find that not all the men who deserve the higher titles are graduates of the schools.

In all ages there has been a demand for men skilled in devising arrangements for the movement of armies, in planning fortifications, in facilitating the management of huge weapons of offensive warfare; and these men were the first to be recognized as engineers. But in these later times great works of public utility predominate over the works for destruction, and there has long prevailed the artificial distinction between military and civil engineering. With the great increase in the number and kinds of large operations called for by our modern civilization, with the great extension of the sciences which are to be studied, a further division becomes necessary. So we already speak of mechanical and mining engineering as other branches.

Civil engineering is now properly limited mostly to the applications of statics; for in the construction of roads, canals, bridges, dams, reservoirs, docks, and water works we are largely concerned with resistance to tension or pressure.

In the utilization of power, kinematics comes to the front, and the mechanical engineer must give to this subject a great share of his attention. He is to make wind, and running water, and steam, and exploding gas, and electric energy, weave gossamer fabrics and spin cables, roll watch-springs and armor plate, drive ships and rifle cannon, drill rocks and print books.

To the study of mathematics and mechanics, the mining engineer must add that of geology and mineralogy. Besides the use of the gentler motors he must learn the rending and shattering force of explosives. He has to sink shafts and drive underground galleries in order to extract ores and other useful minerals; he has to light, ventilate, and drain the rooms; he has to support the roofs; he has to bring the excavated matter to the surface. Above ground the minerals must commonly be subjected to what the Germans call *aufbereitung*, to free them from worthless stuff. And here the proper labors of the miner cease. Others may smelt the ores, and others may use the salt, or sulphur, or manganese, or monazite, for now another science is concerned. Heat and chemical and electrical energies must be brought into play. Those who manage iron furnaces, Bessemer converters and open hearth furnaces, zinc and mercury distilling works, the reduction of aluminum, the extraction of gold by solution, those who have charge of acid and alkali works, of glass works, of potteries, of oil works, of sugar manufactories, of dye and print works, of the manufacture of explosives, of gas works, or of the zymotechnic industries, should be men to whom could rightly be given the title of Chemical Engineer. Their work certainly requires no less knowledge of abstruse principles, no less aptness in planning, than is needed in other branches.

It is true, the mining engineer may sometimes attend to the smelting of ores. But metallurgy is not a proper part of his business. The mechanical engineer may learn to determine the calorific power of coal, though the work really belongs to the chemist. It is possible for the civil engineer to include in his studies the analysis of cements, the sanitary testing of waters, or the purification of sewage; but we should not expect him to be an expert in these chemical and biological matters.

We cannot in all cases draw sharp lines of distinction between the different professions; but each has its special points of view and its peculiar modes of thought. Thus, for the prevention of smoke, one whose mind runs on machinery would try mechanical feeders and stokers and automatic dampers. But experience soon teaches that nicely fitted contrivances are out of place where great heat prevails. The chemist would exalt affinities by heating and compressing the air that is to burn the smoke, or, still better, he would resort to gas-firing.

Civil, mechanical, and mining engineers are concerned with the physical properties of matter as it already exists, and with its changes of place or size or shape. The chemist alone deals with the transmutations of matter in kind. The machinist has evolved that nice combination of valves, piston, crank, and fly wheel, which constitutes the gas engine. But if it is to supersede the steam motors, the chemist must furnish for it a cheap explosive mixture. Wonders have been accomplished in generating and applying electricity, but the problem of supplanting the calorific combustion of coal by a method of fuel consumption that shall generate electricity, is one for the chemist to solve.

Many are the industrial arts that depend on rearrangement of atoms, and very few are the liberally trained men who can give scientific direction to the work. Economical administration calls for such men, and a few colleges are beginning to recognize chemical engineering as a profession to be provided for. Study with reference to this subject in its larger scope, must not be confounded with the narrow courses in chemistry already very commonly established. One may learn to do the routine work of chemical analysis, may talk glibly of atoms and quantivalence and the periodic series, may string out not a few of the numberless rational formulas of organic substances, and yet be quite unfit to direct large industrial operations. Thus, one skilled in laboratory work can easily bleach a swatch of cotton cloth ; but to devise and put in running order the apparatus for bleaching twenty miles of cloth at once, at the cost of a very small fraction of a cent per yard, he must be something more than a mere chemist. I have known students to choose a chemical course because they had proved incapable of proficiency in mathematics. But mathematics constitutes the spinal column of all engineering.

The engineer should be able to look at things on all sides, and therefore his education should be well rounded. The work of his school years must not be specialized too much. But the wants of all parts of the world are not the same, and professors ought by all means to adapt their instruction to local needs.

We should not be too ready to increase the number of titles and academic degrees, for in these latter times they have been so multiplied that it is hard to keep the run of their designating initials. Thus, it seems hardly necessary to distinguish the electrical from the mechanical engineer. But chemistry has an ample sphere of its own and may justly refuse to become a subordinate branch of any profession. Surely the time has come for a course in chemical engineering, with elective variations, to be offered by such institutions as have suitable teachers, books, apparatus, and facilities for observations. General, analytical, and industrial chemistry, electro-chemistry, metallurgy, and mineralogy, must constitute the special subjects; and the regular course should also include all the pure mathematics required in other departments, as well as analytical mechanics, hydromechanics, thermotics, physics, drawing, and the designing of apparatus. It will not do to omit the two modern languages that enable one to make use of the most important scientific periodicals and monographs; and some actual practice in such use is desirable. When we consider that the engineer is not infrequently called on to make out reports, it is evident that for this reason, if for no ther, he should learn to use his own language correctly, clearly, and persuasively.

A suitable course is necessarily extensive and by no means easy, and the average student can hardly finish it in four years, for the chemical work alone will take up a considerable portion of that time. Some time might be saved by a just coördination of the different subjects to be taught; but it is difficult to secure a perfectly fair coördination where each member of a faculty claims an undue share of attention for his particular branch. Time may be economized if the instructors take care to cut out all the redundancies of the text-books. For not a few writers enlarge their works unreasonably by padding with nonessentials. Some propound mathematical or scientific riddles that have no practical application whatever. Of course, many examples should be worked out, to to fix the principles that have been explained and to insure mental drill; but in real life we have to deal with things and not abstractions, and surely just as much mental discipline can be secured by the solution of questions having a direct bearing on professional work as by mere intellectual gymnastics. Prudence would suggest the omission of such unsolved problems as the average student is not likely to work out without help, for what really strengthens the pupil's mental fibre and sharpens his wits is only what he accomplishes by his own earnest efforts.

But, economize all we can, there will still be a lack of completeness at the end of a four years' course. To entitle one to the full professional degree, there should be at least two years of post-graduate study, during which the candidate should take up biology, and learn something of the law of contracts, while he also fills up the gaps that have been left in his previous work.

DISCUSSION.

PROFESSOR JOHNSON inquired to what extent we have in America courses in what might be called chemical engineering, as described in Professor Ordway's paper.

PROFESSOR ORDWAY replied that he believed the Massachusetts Institute of Technology and possibly Cornell University have such courses. He did not know of any others. In reply to a further question by Professor Johnson, he said that he thought there is no such course at Columbia University. He thought that the subject has not been recognized as it should be.

PRESIDENT EDDY said he thought that the University of Minnesota has such a course, but that evidently there is as yet no consensus of opinion with reference to what should constitute such a course; that the establishment of a few such courses would bring that question to a focus; and that naturally this Society is the place where opinions on the subject should first be exchanged.

He thought that the author of the last paper had laid down one or two propositions respecting the study of mathematics to which exception would be taken by most professors of chemistry as well as by those in charge of courses of instruction in mechanical engineering. At least, those things that he had heard from such sources had not agreed with the propositions embodied in the paper.

PROFESSOR JOHNSON stated that that had been the case in his experience. Their professor of chemistry, in first laying down the course in chemistry in the engineering school—and presumably it would be in chemical engineering that the knowledge would be applied in practice,—had deliberately cut out the calculus and all the higher mathematics, and said he did not see that chemistry had any use for that kind of knowledge. He thought that professor could hardly be called a chemical engineer, although the speaker believed he was an excellent chemist and was so regarded by other chemists. He seemed to have entirely overlooked the engineering feature. The speaker had felt for some years that there is in this country great need of courses of that kind. He believed such courses are common in Germany, and he suspected the Germans are the only ones that are well supplied with that kind of instruction. At any rate they seem to surpass the rest of the world in their applications of chemical engineering.

Professor Bull stated that this is a very old story in Germany, as could be understood from Professor Bunte's paper; and he thought that before we do very much more, we might well look to Germany for some advice on the question. For instance, in the school at Zurich there is a very eminent man to teach these branches. The Germans do not employ ordinary chemists to teach the technical applications. They have very eminent chemists to teach the ground work. After that the students are placed under men that have had practical experience, and that actually have been chemical manufacturers, such as Lunge, for instance. The speaker was sure that the consensus of opinion in Germany is that the great progress made in the chemical industry in that country has been due to the chemical engineers. They have special courses in chemical engineering. Degrees are not used in the same sense there as here, but chemical engineers' diplomas are given, and that is what we must come to here. He was sure that if that were done, merchants in this country would not receive from Germany, as at present, anilin colors of the poorest kind, simply because they "do not need any better," as the speaker's brother, who was in that line of manufacture in Germany, had told him. The speaker added that at Zurich they do not give as much time to calculus in this course as in the courses for mechanical and civil engineers.

Professor Kidwell said that it just occurred to him that there is now given at the University of Pennsylvania a course quite similar to that which Professor Ordway had suggested. He did not know the details of the course, because it was put in after his time, but he thought it agreed pretty closely with what Professor Ordway had laid out.

Professor Tyler stated that the course in chemical engineering at the Massachusetts Institute of Technology includes all the mathematics given to the students in mechanical engineering, and nearly all of the distinctly mechanical engineering subjects. The same work is taken in the department of mechanics, in thermodynamics, but not in machine design, and, of course, not all of the shop work. In that respect the course corresponds somewhat closely with that outlined by Professor Ordway. The original plan of the course was made by Professor Lewis M. Norton, who was a chemist and not an engineer, but who recognized most fully the fundamental importance of the engineering side; and the speaker would almost venture to say that he had made that relatively stronger than the chemical side of the course. The course has now been in very successful operation for about six years; the number of graduates is considerable, and they find ready employment. There has been very little alteration in the course.

Professor Ordway remarked that the older chemists perhaps do not understand how great a part mathematics is playing in modern theoretical chemistry. It has come to be very largely mathematical. There is a great deal of physical chemistry in which even the higher branches of mathematics are used; and even to be a theoretical chemist, one should study the higher mathematics. He thought that in many of our colleges the chemists do not appreciate that, because they have not advanced quite far enough. As for designing, he had mentioned the designing of apparatus. Machine design is one thing, the designing of chemical apparatus is quite another thing. Suppose for instance an iron furnace is to be designed. That is a very different thing from a machine. It is a piece of chemical apparatus; it has nothing whatever to do with mechanical engineering.

PROFESSOR WERNICKE stated that he was well acquainted with the institutions in Germany. He would mention only the Technologisches Laboratorium des Polytechnischen Institutes, Charlottenburg, and the Chemisch-Technologisches Laboratorium der Universität Berlin, both of which have very complete courses in chemical technology, as they call it, exactly along the lines suggested by Professor Ordway. In both institutions mathematics, including calculus, is a pre-requisite for the higher courses, and not only that, but also the elements of theoretical physics; and the speaker believed that not one of the professors engaged in these German institutions would agree with those who think that even a part of the requirements in mathematics might be done away with.

PROFESSOR JAMES MCMAHON* stated that Professor Trevor, of Cornell University, gave a course every year in mathematical and physical chemistry; he had studied the subject in Germany, and had given special attention to it. The course is a popular one among the graduate students in chemistry.

PRESIDENT EDDY said it was his impression, although he might be mistaken, that a number of institutions are already reaching out in this direction, though not yet ready to actually announce courses in chemical engineering. The work is thus starting in a tentative way.

---

*Assistant Professor of Mathematics, Cornell University, Ithaca, N. Y.

PROFESSOR MAGRUDER stated that at the Ohio State University they considered something of that kind the previous year. The professor of chemistry and the speaker talked it over, but found that it was absolutely impossible to get the desired amount of work into four years. If they could have adopted the suggestion made in the paper and induced the students to return for another two years they might have been able to arrange it; but requiring four years of chemistry, and giving from two to four years to each of the other subjects usually found in such courses, there was very little time left to assign to the distinctively mechanical engineering subjects. As a result, they compromised the matter; and they now have a course in chemistry in the College of Engineering distinct from the course in chemistry in the College of Arts. The speaker's experience in that line led him to think that the chemical engineer needs a great deal of mechanical engineering. Take, for example, the illustration given by Professor Ordway. The speaker had once gone to Louisiana to test the boilers of a sugar mill or factory. The mill was stopped, as a vacuum pan had broken down. The men did not seem to appreciate the fact that a pressure of from twelve to fifteen pounds per square inch means a large total force. They were deficient in knowledge of mechanics and strength of materials. The speaker was of the opinion that if the student in chemical engineering were taught how to apply the principles of the strength of materials to chemical design as they are applied to machine design, he would be a more successful engineer, being better supplied with the tools of his profession.

THE TEACHING OF MACHINE DESIGN.

BY J. J. FLATHER.

Professor of Machine Design, Purdue University, Lafayette, Ind.

During the Brooklyn meeting of this Society the writer presented a paper on "Mechanical Drawing in Technical Schools," that included a discussion of the general subject of machine design. In the present paper no attempt is made to suggest the ideal or most desirable course in machine design; the paper is simply a description of the work and the methods used by the writer in his own classes.

Mechanical drawing and machine design are different subjects, and it is assumed that the student understands thoroughly the principles of projection, and can execute a neat working drawing before taking up machine design.

Applied mechanics and the strength of materials are closely allied to machine design, and are essential to a complete mastery of the subject, but it is not essential, in the opinion of the author, to study these subjects before entering upon the problems of machine design. In the present case the student is given a summary of the principles and general rules of calculation that are applicable to problems that may arise in the determination of machine parts, together with a discussion of the general properties of the principal materials with which the engineer has to deal, to the end that he may be equipped with suitable tools early in his work. This will enable him to design intelligently those simple elements of which a machine is composed. The work is carried on by means of lectures and recitations preceding each series of exercises, which latter are calculated and developed in the drawing-room, where opportunity is afforded for comment and criticism on the part of the instructor.

The work is taken up at the commencement of the junior year, beginning with a series of six problems which are given to all the engineering students, mechanical, electrical, and civil. The character of the problems is varied, as far as may be, and adapted to the requirements of the different branches of engineering. Each problem involves the same general principles, but by varying the data so that the design bears some relation to the future work of the engineer, a greater interest is maintained.

Separate problems are assigned to groups of individuals, who are at liberty to consult with each other regarding the work during its progress. This matter of consultation between the various members of the class has many advantages, since it stimulates discussion and promotes a more thorough observation of details—a habit which can not be too strongly urged upon the student.

Calculations and sketches are preserved in a suitable scratch book, made from cross-ruled manilla paper, and while a few of the men may copy their calculations, yet the number is very small, and in any case the instructor may ascertain, by a few judicious questions, the extent of an individual's knowledge regarding any particular problem or drawing. An antidote for this trouble is to assign the student data different from those given to the other members of the class.

The aim being to give instruction in machine design from an educational standpoint, the work of calculation forms no small part of the course. The drawing is a mere detail of the work; yet it is essential to a proper comprehension of the subject that a drawing be made of every part calculated, and moreover, that the drawing conform to practical shop requirements in its form, proportions, and sizes.

Machine design cannot be properly taught without drawing-room applications. In this work the technical instructor has ample field in which to correlate the apparent discrepancies of theory and practice. Rational and empirical formulas must necessarily be associated, often in the design of a single piece, and the student must be taught their relation and the principles underlying their application.

One of the most difficult things for a beginner to learn is how large to make a part after the size has been determined by calculation. No definite rules can be given, but many ways will suggest themselves by which this economic feature can be incorporated with the design. Tables of standard sizes and blueprints from prominent manufacturers are important elements in this work, and the student should be frequently referred to them for comparison and corroboration.

In the actual work of calculation, the use of the slide-rule is urged upon the student, and the various engineers' pocket books, such as Kent, Nystrom, Haswell and Trautwine, are constantly consulted.

As stated, the first work which the writer gives to his students in machine design consists of a series of six plates involving calculations and drawings for the following:

Plate I. *Fastenings; riveted joints.* Determination of plate thickness in boiler shells and stand pipes; size and pitch of rivets; end plate connections; stays.

Plate II. *Fastenings; screwed pieces.* Size and number of stud bolts in steam cylinders, pumps and pipe flanges; piston-rod ends; connecting-rod ends; adjusting screws; screw-eyes for lifting dynamos; truss rods; crane studs in shear; ditto, in tension; turnbuckles; screwed ends of tension members and similar work.

Plate III. *Fastenings; various kinds of keys.* Sunk keys; feathers; Woodruff keys; pins. This work involves the calculation of shafts for all kinds of general work; hoisting-crabs; machine shafts; line-shafts; jack-shafts; water-wheel shafts; dynamo shafts.

Plate IV. *Fastenings; various kinds of shaft couplings.* Flange, compression, sleeve, dog, spiral clutch and other forms. This also involves calculation of the necessary shafts, and includes the calculation of jack-shafting and line-shafting for an assumed factory.

Plate V. *Gearing; profiles of teeth.* The mere profile of tooth surface, without reference to proportion of tooth. The forms drawn are involute, exact method; ditto, approximate method; ditto, Willis' method; ditto, Willis' odontograph. Epicycloidal, exact; ditto, approximate (Reuleaux); ditto, Robinson's odontograph.

Plate VI. *Gearing; outlines and proportions of teeth.* Radial flank teeth; teeth for given arcs of recess and approach; maximum arc of contact; rack teeth. In this plate and the preceding one, a few simple forms of teeth are drawn that give the student some practice in the application of principles studied at this time in the recitation room under the head of "Mechanism."

Preceding the first four plates, lectures are given relating to the work in hand, and the students are sent to the board to work out similar problems or parts of problems before the class. No especial text-book is used, although each student is provided with some one of the various books on the subject; among these are the works of Reuleaux, Unwin, Low and Bevis, Klein, Welch, and the "Stencil Notes" of the writer. In addition to these, Kent's "Mechanical Engineers' Pocket-Book" is very much in evidence. The advantage of having various works of reference increases the benefits obtained by the students in consulting one another regarding their work. The principles involved are necessarily the same, although there may be some difference in detail among the different authors when proportioning parts by empirical rules. But this simply accentuates the fact that there is no exact standard for much of the work of the machine designer; and it is well that this should early be brought to the attention of the student.

Upon the completion of the work, as outlined, a written examination is given, and this is divided into two parts: the first covering fundamental principles and rules which the student ought to have at his finger-tips; the other involving less general matter. For the second part of the test, the student is allowed to consult any available books or notes which he may have.

The idea is not that the student should memorize a lot of miscellaneous rules and proportion of parts, but that he should be able to apply correctly the principles governing given conditions, and to design a part or combination of parts, readily and intelligently.

At the beginning of the next term the work is continued for the mechanical and electrical engineers, and five more plates of machine elements are designed. These are:

Plate VII. *Gearing.* The design of a spur gear to transmit a given load or horse-power at a known speed (or other suitable data), including the calculation of shaft, size of hub, proportions of arms and rim sections, pitch and face of gear.

Plate VIII. *Gearing.* The same as Plate VII., but for a pair of bevel gears, and including the development of the tooth outline.

Plate IX. *Pulleys.* Belt wheels and fly wheels.

Plate X. *Pulleys.* Rope wheels.

These problems involve the determination of shaft diameter, width of belt, size of arms, hubs, set screws, diameter and number of ropes, weight of rim (for fly wheels), calculation of rim and hub bolts, flanges and connections for segmental fly wheels. The problems in rope transmission involve both American and English systems, as applied to dynamo and mill work.

Plate XI. *Bearings.* An exercise involving the sizes of shafts and the proportions of bearings for a variety of work, including brass boxes for machine tools, babbited boxes, dynamo sleeves and bearings for saw mandrels. Methods of lubrication are considered in each problem.

Upon the completion of this work a short course on the design of valve gears is given. This part of the subject is taught by means of lectures and notes, in connection with the work in the theory of the steam engine, to which it is supplementary.

In teaching this subject the writer has obtained excellent results by having the student solve a few problems and construct a working valve and valve-seat from card-board. This is done outside of the class or drawing-rooms, as a part of the preparation required for recitation. The relation between the valve diagram and the port openings is very readily comprehended by this method.

In addition to the preceding work, the mechanical engineering students are given short courses in roof trusses and kinematics. Thus at the beginning of the senior year the men are in a position to do good work in advanced design.

With the exception of the preliminary work in steam engine design, individual problems are assigned in the senior year, and the work is graded to suit the abilities of the men. In assigning a problem the general requirements are specified in writing, and references to catalogues, books, and articles in current technical literature relating to the work are quoted, and the student must look these up and prepare sketches and an outline of procedure, which he discusses with the instructor before beginning the working drawings.

The tracings are all made from pencil drawings. There is no inking of drawings in the senior year. In the first series of exercises the drawings are pencilled and not traced; these are exercises for teaching the theory of steam engine work. The later work is done on similar sheets in pencil. These are not inked, but are traced. The junior drawings are all inked in, to give the student practice in finishing the drawings. Nominally six hours a week are given to the work, throughout the junior and senior years. The special work in kinematics increases that, bringing it up to about eight hours a week for the mechanical engineering students, in the last half of the junior year.

In all the work, especial attention is directed towards familiarizing the student with practical drawing-room and shop methods, and manufacturers' catalogues and blue prints are freely consulted for comparison and suggestion throughout the advanced work, although from the nature of the problem these cannot be used as copies. The aim is to teach machine design, not merely drawing; and this the author thinks is well attained, in the limited time allowed for this subject, by the methods described in the paper.

Discussion.

Professor Ordway said that there is a point in which teachers sometimes fail. He recalled a mistake that was made in designing a gear wheel. When the pattern was made it was found that the wheel could not be cast because the proportions of the hub, rim, and arms were such that the arms invariably broke in cooling.

The speaker thought that considerations of shrinkage are too often omitted in the instructions that are given; that some attention should be given to proportioning parts so that they may be cast properly. Even if the casting does not break in cooling, still there are in some cases very great stresses, so that in the use of those parts they are liable to fly to pieces.

Professor Flather thought that to be one of those cases in which, as he had stated, theory and practice can be correlated very nicely by the instructor.

Professor Ordway added that he thought the designing of such things as vacuum pans should be done by the chemical engineer. The speaker had a good deal of experience in chemical designing, the larger part of which had been in the designing of furnaces, which no mechanical engineer, no one who was instructed in machine design merely, would be at all competent to do. The mechanical engineer would be entirely at a loss in designing a furnace, for instance, a reverberatory furnace for a particular purpose. The speaker had had to design a furnace in which he could melt a half ton of glass by reverberated fire. He would defy any mechanical engineer to make a design of such a furnace as that, even with a good deal of study. He must have a good deal of practical experience, and that can be acquired only by having actual charge of the things themselves and seeing how they work in practice.

Professor Bull said that, as a mechanical engineer, he would not allow the profession to be maligned in that way. He thought that a mechanical engineer ought to know how to design a furnace.

Professor Ordway said he had seen some queer instances of lack of design in such cases. He once had to take charge of some chemical works in which the chemist who had preceded him had built a reverberatory furnace that did not draw well. The speaker found that it took nearly all day to work a charge in the furnace that should not have required more than two hours. He had the fires let down, got into the furnace, and found that the throat through which the flame passed over the bridge from the fire to the hearth was just about large enough for him to get his hand in, instead of being about ten inches wide, as it should be.

Professor Bull :—Was that designed by a chemical engineer?

Professor Ordway :—It was designed by a chemist.

Professor Magruder asked whether that was the fault of the chemist or of the mason. Very frequently the mason does just that thing in boiler setting, and it is almost necessary to stand over him with a shotgun to prevent him from doing it.

Professor Ordway maintained that the chemist is responsible for such things as that. He himself would never allow a mason to do the work just as he pleased. He always looked after that every hour or so. The masons would sometimes say that a certain thing could not be done, and he had sometimes had occasion to take hold and show them that it could be done.

Professor Magruder said that he had had the same experience.

Professor Kidwell said that he had once had to execute a design made by an excellent chemist and metallurgist; the constructive details proved so inferior that the whole thing had to be designed anew. But it did not appear to him that either this case or any of the others cited had any bearing on the subject introduced by Professor Flather. He did not believe it possible, in any instruction in machine design forming part of an undergraduate course, to convey to the student the kind of information which can be gathered only from long practical experience. Take, for instance, the gear wheel mentioned by Professor Ordway. The speaker had seen numerous cases where it was supposed that such work could not be executed in conformity with the drawings, but he had afterward found a man who could do it. The whole trouble was with the moulder, who tried to throw back on the designer the blame for failure, which was really due to his own lack of skill. Such matters could not be taken care of in any scheme of instruction limited to the time Professor Flather had at his disposal. The whole object of the paper, as the speaker understood it, was to outline a course in which the student is to be introduced to machine design and is to obtain a solid foundation in the general principles of the subject, so that later on he will be prepared to apply them with success to any particular problem, the requirements of which he can learn only from actual practical experience. It seemed to the speaker that Professor Flather had taken particular care to make this clear.

As one who had done some work of this kind, the speaker could appreciate the large amount of labor Professor Flather had expended in laying out this scheme, and he wished to express his gratitude for the ideas which the paper had given him. He would particularly emphasize one fact which no doubt all had noticed, namely, that all through Professor Flather's course the student is forced to do what the vacuum-pan designer did not do—bring into play a large amount of common sense, to supplement his knowledge of engineering.

THE EFFICIENCY OF TECHNICAL AS COMPARED WITH LITERARY TRAINING.

BY T. C. MENDENHALL.

President, Worcester Polytechnic Institute, Worcester, Mass.

The Society's Secretary has put the title of my paper in words appropriate to the proceedings of an Engineering Society, and he has made—unconsciously, I have no doubt—the very phrase in which the controversy is outlined an argument in favor of one side of it. I can do no better, therefore, than to make my brief discussion of the subject on the model which he thus sets before me. If there be any superiority in scientific or technical training it ought to be evident in simplicity, clearness and definiteness of expression, and especially in the absence of anything like confusion in the meaning of terms. A body of engineers may therefore properly expect some preliminary consideration of the signification of the words that are used in describing the two notions about to be contrasted.

In this presence not much need be said about the meaning of the word "efficiency." One of its definitions in one of the great modern dictionaries is, "the quality or power of producing desired or intended effects," and this meaning may well be kept in mind in the present discussion ; but it is also defined in the same dictionary as " the ratio of the useful work performed to the energy expended," which is, on the whole, a more definite and satisfactory rendering.

We are to consider, therefore, two processes, the one called "technical training," the other, "literary training," with a view of determining which gives the higher percentage of useful output for a given amount of energy expended. In measuring the latter, the unit of time may be used without serious error; that is to say, it may be assumed, with a sufficient degree of approximation, that the energy invested in a technical or a literary training is proportional to the time spent in its acquisition. This is by no means rigorously true, but it is true enough for the argument, and far more nearly exact than many other statements with which we shall have to deal.

Furthermore, with an equal degree of approximation it may be said that with an essentially equivalent amount of training preliminary to either of the special processes under consideration, the same number of years is usually given to their accomplishment; so that it may be fairly assumed that the invested energies are equal. This makes relative efficiency depend on a comparison of the useful output or outcome of the methods of training, a task of great difficulty in the absence of a definite unit by which this output can be given numerical expression. Imagine for the moment that we have two young men, precisely alike in physical, moral, and intellectual qualities; that they received essentially identical training until, in their preparatory school, it became necessary for them to make special preparation, the one for a course of four years in a literary collegiate institution, the other for a course of the same number of years in a scientific or technical college; at the end of it all, which will be the better equipped for the responsibilities of life? Which the more useful man, the better trained man, the *better educated man?* The difficulty of the problem is increased by the evident impossibility of "starting fair" in such a race, a slightly greater natural leaning towards one subject, or an inherent taste for another, being almost inevitable; but in any attempt to solve the problem we are bound to inquire and to define what is meant by "better equipped," "more useful," "*better educated.*"

As everybody knows, the whole controversy turns upon the meaning of these phrases. Could we all agree upon the qualities and accomplishments that combine to make a "liberal education," we should not be long in agreeing as to the best way of producing them.

It is important to note, before going further, that the word used to describe both processes is "*training,*" which in these days is usually understood to mean a special preparation for the performance of a particular task or series of tasks. A man "trains" for an athletic contest, and, indeed, following the modern practice of specialization, he trains for the particular kind of athletic competition in which he proposes to engage. The dangers and evils of specialization in intellectual training are perfectly reflected in the gymnasium, in the field, and on the track. The "all-round" athlete is now seldom heard of, because glory is found only in doing some one thing a little better than any one else, and this can be obtained only by restricting one's training to what is necessary for that one thing. But no one will seriously contend that this system, which college authorities have not the courage to throw off or even to improve in any degree, does much for the symmetrical development of physical manhood, nor can it be denied that a parallel course in intellectual training must as certainly produce unsatisfactory results. But fortunately our management of the gymnasium for the intellect is still superior to the average college supervision of physical culture. Something is still done, or attempted, for every man; and the time has not yet come when the entire educational forces are concentrated upon a handful of selected men that are to be cheered on to mathematical, linguistic, or scientific victory over a similar group from a rival institution, by their fellow-students, who shout themselves hoarse on the arena benches. That such a time will not come in the near future must be attributed to the difficulty on the part of the spectators of recognizing scholastic triumph, and the consequent danger of "dilating with the wrong emotion."

If, therefore, the word "training" were to be used in the very restricted sense that is now all but universal, the battle would be won for the technical and scientific schools before the first gun is fired, as no one will venture to deny the fact that in the fitting of men to perform specific tasks the efficiency of those schools is vastly greater than that of their literary competitors. Indeed, this fact, which implies the semi-professional character of their training, is often held against them in discussing their claim for consideration as educational institutions in the best, if not the broadest sense. Although we are usually the challenged party, and hence entitled to the choice of weapons, confidence in the justice of our position makes us generous; and in order that the question may be sufficiently comprehensive to cover all disputed ground, the word "training" will here be assumed to mean "education" in its highest signification. It now becomes necessary to inquire what is the generally accepted meaning of "education," or what are or should be the visible, tangible results of the process of educating, by which the efficiency of the two schools shall be judged? Here, again, the dictionaries, great and small, are not extremely satisfactory, but there are some things worth quoting. Says one, "Education, in a broad sense, comprehends all that disciplines and enlightens the understanding, corrects the temper, cultivates the taste, and forms the manners and habits." Again, specifically, "intellectual education comprehends the means by which the powers of the understanding are developed and improved, and knowledge is imparted;" "esthetic education is the development of the sense of the beautiful, and of technical skill in the arts;" "technical education is intended to train persons in the arts and sciences that underlie the practice of the trades or professions."

The underlying, common, great thought, here and in other examples, is that of the development, discipline, and mobilization of the powers of the human intellect. After all, nothing better exists than that famous description of a liberally educated man given by Huxley, himself a splendid exemplar. It may be quoted as likely to be accepted by all parties to this discussion. He says: "That man, I think, has a liberal education, whose body has been so trained in youth that it is the ready servant of his will, and does with ease and pleasure all that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength and in smooth running order, ready, like a steam-engine, to be turned to any kind of work and to spin the gossamers as well as forge the anchors of the mind; whose mind is stored with the knowledge of the great fundamental truths of nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions have been trained to come to heel by a vigorous will, the servant of a tender conscience: one who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to esteem others as himself."

This, then, represents broadly the end towards which all training ought to be directed, and that system is most efficient which, for a given investment of energy, most nearly approximates to this result.

But before the question can be satisfactorily discussed, there must be substantial agreement upon two other terms—what constitutes a technical or scientific education, and what a literary education? Here we meet with almost infinite variety in opinion and practice, but we shall have little difficulty, at least for the sake of the argument, in differentiating these two great and now contemporaneous, but not necessarily opposing educational systems.

Let us first consider a "type specimen" of a course of study leading to the degree of Bachelor of Arts in what is ordinarily known, and hence best described, as a "Classical College." As such I have chosen a well and widely known institution, that, while recognizing the importance of the scientific element in education, and maintaining some excellent departments of science, presided over by men distinguished in their specialties, grants but one degree to undergraduates, that of Bachelor of Arts. In the course leading to this degree, some electives are allowed from the beginning of the sophomore year, and some of these are in science subjects. I have assumed a tolerably strong leaning towards science in making up the four years' course, and there is no attempt to show how completely a man *might* avoid contact with modern scientific thought. For convenience in making the comparison, all studies are grouped under three heads: literary, mathematical, and scientific. The classification is by no means strictly logical, but it is convenient, and as it is followed in both cases it is fair. In a rough way, under literary subjects are included all language studies, history, economics, etc., all, in fact, which is neither pure mathematics nor natural science, nor the applications of either to technical professions.

Under this classification the total energy expended in obtaining an education in the classical college (taking no account of losses due to wasteful radiations, unnecessary friction, etc.) is distributed about as follows:

Literary Subjects	67 per cent.
Mathematics	16 "
Science	17 "

It is believed that this is a fair representation of what is known as the classical or literary course in our best institutions.

As a type of what may be called "technical training" in the sense in which I have assumed the phrase to be used in the present discussion, I have selected two courses of four years each, as offered in two well-known engineering colleges. From one, its course in civil engineering has been chosen, and from the other, that in mechanical engineering. The subjects in these courses have been grouped as above, and then the mean of both is accepted as a fairly approximate type of this sort of educational work. The literary and the mathematical subjects are essentially the same in kind as those described above, but under scientific subjects are included a large number which are more properly defined as "applied science." The distribution in this technical and scientific course is as follows:

Literary subjects	19	per cent.
Mathematics	21	"
Science and applied science	60	"

It may be worth while to say that a subdivision of the last of these would allot about 18 per cent. to pure science and about 42 per cent. to applied science and "technics." It is also worth noting that the scientific course gives more energy to literary studies than the classical course does to science.

I hope it will not be considered a serious fault that the greater part of this paper has been devoted to an attempt to put the question under discussion in such terms that there is little chance for misunderstanding.

If there is no serious dispute as to the propositions thus far laid down, the controversy will be greatly simplified and shortened.

It only remains, therefore, to determine which of these two schemes of undergraduate work has been or is likely to be most effective in producing that "liberal education" which Huxley has so clearly defined. The first paragraph of that wonderful characterization refers to the training of the body, which is satisfactory when it is "the ready servant of the will, and does with ease and pleasure all that, as a mechanism, it is capable of." Perhaps neither literary nor scientific institutions can claim to be highly efficient in respect of this element of a liberal education, in spite of the millions of dollars invested in gymnasiums, athletic fields, tracks, etc., for, as has already been pointed out, their use has mostly degenerated into a real abuse, in the specialization and excessive training of the very few, that these may furnish amusement and excitement for the many. For scientific schools it may be claimed, however, that they are not only much less guilty in this respect, but that a good share of their training, in drawing room, laboratory, field practice and workshop, does much to make man's body "the ready servant of his will," and to discipline his muscles, nerves, and senses in the performance of many difficult and delicate operations, to the end that his deftness of hand, acuteness of vision, and muscular sensibility combine in enabling him to nearly satisfy the requirements of a perfect mechanism.

In the second paragraph, Huxley says that a liberally educated man must be one "whose intellect is a clear, cold, logic engine, with all its parts of equal strength and in smooth running order, ready, like a steam-engine, to be turned to any kind of work and to spin the gossamers as well as forge the anchors of the mind." Here the intellect of man is considered as a mechanism, one which should be at once comprehensive in the range of its operations, and accurate and certain in its results. It should, in its way, resemble a testing machine capable of crushing a beam resisting a pressure of a million pounds, or of showing, within a tenth of one per cent., the tensile strength of a fibre of silk; it should be like a powerful but perfectly controlled steam-hammer, with which one may forge the shaft of an ocean steamer or crack an egg-shell without disturbing its contents. The comparative efficiency of the two schools in respect of this element has been and will continue to be much discussed. If any function is developed and perfected by use, however, it cannot be denied that here, also, scientific and technical training has the best of it. While no one can doubt the disciplinary effect of language studies, no one can claim that in the cultivation of the reasoning powers, the power of protracted, serious, and productive thought, they are at all comparable with mathematics and science. In the study of mathematics one is trained in pure logic; the study of science enables one to understand the great fundamental laws by which the natural world is bound, and the fundamental properties of the materials of which that world is composed. It is in the application of the logic of mathematics to the facts of science that man's intellect finds its most exalted and most fruitful occupation.

In the laboratory, in the field, and in the lecture room, the student of science is ever in the presence of things yet unexplained, and is constantly inspired to seek relations and extensions of known phenomena by which they may be included. The power of clear, clean thought is so necessary to his progress that its cultivation is indispensable to him. Is it not impossible to conceive of one trained in applied science, whose mind is not, in a large degree, "stored with the knowledge of the great fundamental truths of nature and of the laws of her operations?" Can it be seriously claimed, therefore, that in respect of the second requirement of a liberal education, the greatest efficiency lies with a scheme in which from one half to two thirds of the invested energy goes to the acquisition of only an imperfect knowledge of languages in which men two thousand years ago expressed thoughts and opinions, a large share of which have, in themselves, little, if any value at the present time? Finally, there remains the cultivation and development of moral qualities, the last, but after all, the most important of the triad of educational essentials. In this field, also, the advocates of scientific training may claim much. In no other kind of discipline is the value of honesty, which is almost the foundation of all virtues, so clearly demonstrated; and none other so perfectly inculcates respect for the opinions and judgment of others. It is best by the study of nature, and especially by admission to that inner court to which science alone furnishes the key, that man learns to love all beauty and to hate all vileness. The moral qualities that grow out of and harmonize with a recognition of the invariability of the laws of nature, are much nobler in kind than those that spring from tradition, fear, or superstition.

It is often urged that classical and literary subjects are of first importance because by them men may know man, his nature and disposition and the motives by which he is governed. After some thousands of years of opportunity not much, apparently, has been accomplished along this line.

It is argued that a knowledge of ancient tongues opens the door to a literature of great beauty and excellence. It is doubtful if this knowledge is sufficiently good, on the average, to open the door wide enough to afford more than an unsatisfactory glimpse; but in view of the many excellent translations of this literature, made by competent experts, this argument is not more reasonable than the assumption that it is necessary for every man to possess a telescope of forty inches aperture, that he may understand the great facts of astronomy and know something of the system of the world.

The study of ancient languages is believed by many to be a necessary preliminary to the easy, accurate, and graceful use of our own tongue. That a degree of facility in speech and writing is gained by the study of other languages cannot be denied; but the enormous importance of such study is rendered doubtful by the reflection that a thinking man is perhaps a higher product than a talking man, and that the people whose linguistic power in essay and oration has most commanded our admiration knew no language except their own.

Attention is often called to the commanding influence and high standing of men born and for the most part reared in the country, as compared with those who are city bred, not only in politics and statecraft, but in commerce and the professions, not excepting literary pursuits. This is to be attributed, in my judgment, to the broadening and strengthening character of their early training, not in the school-room alone, but during all of their waking hours. The multiplicity of occupations in the country, in all of which the young man engages; the familiarity with all sorts of handicraft which country life compels; the resourcefulness, the dependence upon self, and especially the cultivation of habits of observation and deduction in the uninterrupted opportunity for the study of the phenomena of nature that the life affords—all of these combine to form a curriculum identical in underlying principles with those of our best scientific and technical schools, the end of all being to produce men that shall observe carefully, think clearly, reason soundly, and speak deliberately.

It is not for a moment contended that the training afforded by even the best of our scientific and technical schools is perfect, or even approximately so. Our contention is only that when two courses of study are contrasted, the one assigning two thirds of the energy expended to language studies, the other about the same proportion to science and its applications through which the forces and materials of nature are made tributary to the comfort and happiness of man, the latter may well claim a higher percentage of efficiency, even if the useful product is restricted to what is called a "liberal education;" for as Priestly said, a hundred years ago, "by these sciences also it is, that the views of the human mind itself are enlarged, and our common nature improved and ennobled."

DISCUSSION.

DR. MURKLAND inquired if there was any intimation in the paper whether the percentages take into consideration the number of hours devoted to each class of studies, or simply the number of studies. He asked because he gravely doubted whether such a ratio holds good if the time given to the studies be taken into consideration.

PRESIDENT EDDY replied that it was his opinion that that was the intention of the author of the paper, and that many of those percentages agree in general with percentages given in papers heretofore read before the Society, containing very careful estimates from comparisons in a large number of institutions. This statement had reference especially to the scientific and technical side of the question. The other side had not been quoted so much; but the speaker thought all would agree that more than one half of the work in the classical course of study is of this literary, sociological, and philosophical nature.

PROFESSOR ALLEN called attention to the fact that the paper states that the total energy expended is divided in the proportions mentioned; he thought that with a careful man like the writer of the papers, that would almost necessarily mean that the proportions are, not those of the numbers of subjects, but of the time used with them.

President Eddy stated that Dr. Mendenhall had long been a student of curricula and it was hardly possible that he would make a mistake upon any such point as that.

Professor Kidwell asked whether Dr. Mendenhall is a classical scholar.

Professor Mees thought the answer to that question would hinge upon the definition of a "classical scholar." According to the speaker's recollection, Dr. Mendenhall had at least four years in Latin, and two in Greek. As far as the speaker knew, that satisfies the definition of a classical scholar. At any rate, he had had the advantage of the study of foreign languages.

Professor Kidwell thought the controversy on this subject is usually conducted in anything but a fair spirit, the reason for it being, it seemed to him, that the one party seldom tries to ascertain what the other is striving to do. He did not believe that there is any antagonism at all between classical or linguistic studies, on the one hand, and scientific studies, on the other hand, nor that one kind is more efficient than the other, provided that we keep in mind the purpose for which each is taken. No matter how well conducted, the scientific course will not do that which the classical course will do, and *vice versa*; nor did the speaker think that any one who had had an equally good training in both would assert such a thing. He did not believe there is any course in science that will train a man to think more carefully, readily, honestly, or acutely than a thoroughly good course in the classics, supplemented by rigid instruction in logic and metaphysics. He was one of the unfortunates who had to go through a course of that kind before taking up science, and judging from his own experience, he thought there had been just as much reasoning power developed by the first course as by the second. Furthermore, the purposes of the two courses are by no means the same. A scientific course, for instance, enables a man to encounter physical realities and turn them to advantage, while a classical course is rather for the purpose of training a man's taste and better equipping him to mingle with and persuade his fellow men; hence the speaker did not think that either course would serve the same purpose as the other. As to the contention that the scientific course is the more efficient, and that training in classics produced mere talkers—parrots, in fact—he thought there would be some difficulty in proving it. He wished to cite one case. The Constitution of the United States was produced by men who had some initial common sense and a good deal of power of thinking. He did not know that there were many scientific men among them, but there was a great number of classically trained men. In saying this he did not wish to underrate scientific study, because he personally preferred that side; but he thought we should be fair to each side.

Dr. Murkland said that the only point upon which the question arose in his mind was as to whether it is true in general that literary studies are taught in the technical colleges to a somewhat greater degree than the scientific studies are fostered in the classical colleges. That was a point that had been advanced, but he thought it open to question.

The speaker said he was reminded of Charles Darwin's autobiography, wherein he recorded the loss of some of the characteristics which he might have kept if he had not sacrificed them to his scientific eminence. The speaker also remembered hearing a mechanical engineer, when he was shown a copy of Naujock's "St. Cecilia," remark concerning the halo that it was a very excellent ellipse—which was of course entirely a joke, yet the joke had its point. If the speaker understood the object of a literary training, it is not to make a talking man, but a sympathetic man; and the quality of intellectual sympathy is much more valuable than the ability to talk. As has so often been said, there is a danger of a loss just along this line. However, no one could wish to take the position of *advocatus diaboli* in a case like this; and the speaker wished to say, as of course every one would, that he had been charmed with the paper. He recognized that, if not to-day, at least in the near future, when the technical colleges shall have become more nearly what they are aiming to become, it will be true in general that the technical course will be equal in its resultant efficiency to the literary course. But the paper evidently is prophetic. In its general purport, it does not speak so much of the course existing in any school, as of the ideal course, and in that respect Dr. Mendenhall's paper is worthy of all commendation.

Professor Kidwell said that even allowing that the two courses may be equally efficient, the results obtained are entirely different and are knowingly sought for different purposes. This point seems to have been entirely forgotten in this and other similar papers.

Professor Lambert wished that Dr. Mendenhall had calculated the efficiency of a combined literary and scientific course. Lehigh University had been almost altogether a technical institution, but they had introduced such a combined course, in which men who could afford to give six years of their time might devote two years to literary studies and then begin their professional engineering studies.

Professor Galbraith thought that possibly the reason why Professor Mendenhall did not attempt to do so was that combined efficiency is usually computed by multiplying the separate efficiencies; thus if one were .8 and the other .9 the combined efficiency would be .72.

Professor Constant remarked that perhaps it is only fair to remember in connection with the paper that the definition of the educated man, which forms the basis of comparison in the paper, was uttered by a scientific man.

Professor Waldo thought there was one other point that should have been brought out in the paper. He did not see how a comparison such as was instituted in the paper could fairly be finished until a sufficient number of men who had been educated in the one way should be compared with an equal number of men who hád been educated in the other way —not only with reference to the average result at the end of their college training, but also at the end of their lives. It seemed to him that the whole matter depends upon the amount of energy induced ; energy which might be in a certain sense potential, and developed further along.

President Eddy held that it was a judgment upon this very question that the public is now passing upon education.

Professor Johnson said he would like to contribute to the discussion a few thoughts which had come to him since hearing the paper read. It seemed to him that Professor Huxley's definition and the basis of the paper were founded on what may be considered an altruistic view of life rather than an egoistic one. If mankind looked upon the individual as a kind of mechanism, to be worked for the benefit of the whole, then Huxley's definition and the argument of the paper might be accepted, as well as the conclusions that were reached. But as individuals we like to look upon ourselves as factors with somewhat egoistic interests, and the speaker thought that the motive of self-interest is a legitimate one. From that point of view, of making the most of ourselves in this world, both in the matter of enjoyment to ourselves and to our friends, and in "getting on in the world" in the vulgar sense of being prosperous, which is not without its compensations, the speaker thought the paper one-sided. He had sometimes said that the human mind is not a warehouse but a workshop, and the old ideas that "knowledge is power" and that we should "store our minds with useful knowledge," and so on, are rather vicious, because they make of the man a sort of warehouse rather than a workshop, or a machine, as Dr. Mendenhall puts it. The speaker thought, however, that the mind should be something more than even a workshop, something more than a machine to be worked for the benefit of society. He thought that man ought to have some means of entertainment and enjoyment in his mental house, and that there should be a little reception room kept for his friends; he should have something of a library; and he should be able to take some ease and comfort, and be a source of satisfaction and joy to himself and his friends, as well as a means of pushing the world along. For that reason the speaker thought the education of engineering students should include the humanities as well as a knowledge of the laws and forces of nature. If the engineer were to be put into a dead world and expected to reconstruct it, as engineers are reconstructing this world, and if there were no human history, no human interests, no men to control, to direct, and to interest, then the definition of Rankine, that the engineer is a man whose business is to direct the laws and forces and materials of nature for the convenience and happiness of man, would be a sufficiently inclusive one. But when we educate a young man, even though we expect him to became an engineer, we should include more than these material subjects in his education. He lives among men; he must direct men, and direct capital; and the engineer would do very little toward directing the laws and forces and materials of nature for the convenience and happiness of man if he did not have some control of capital and of the man who owns the capital. The professional man is a failure unless he is professionally prosperous; and as a means of professional prosperity, therefore, some greater breadth of training than our engineers are now getting is not only desirable but quite essential. On the other hand, the drift is more and more toward narrowing the courses of study, toward restricting those courses to the purely professional subjects. Now, this Society is composed of teachers, and as such the Society is expected to aid largely in directing engineering instruction, not only in this country, but perhaps incidentally in other countries; and the speaker believed it is doing it. There is, therefore, in this particular a great responsibility resting upon the members of this Society. The more they persist in emphasizing the technical side of their courses of study, the more they will help on this drift, which the speaker believed to be rather away from the true course than toward it. If they lean at all from the vertical they ought to resist this tendency, leaning rather in the other direction. He believed greater preparation should be encouraged in classical directions, in the humanities, in the languages, and in those subjects and directions in which mankind has a history and an interest; that there should be more of that education that our classical friends persisted in calling education solely. They regard as an educated man, only the man who shares the education that they have. The more we exclude the education which they have from the education that our students receive, the more will they look upon our graduates as an uneducated product in their sense, there being so little in common; nor could they be blamed very much. The more liberally our students are educated, the more interest they have in society, the more they know of the history of the race and its institutions, the more they are broadened on the humanitarian side, and the better they are capable of mingling with and directing men, the more prosperous will they become in purely professional lines. We ought, therefore, to insist on greater breadth. How to secure it is another matter. The speaker suspected that the only practical way of securing it is, not to demand it, but to encourage students as much as possible in acquiring this breadth of training before entering upon their technical courses. That is practicable as a moral argument. If he understood the true drift of the paper of Dr. Mendenhall, it seemed rather against acquiring this literary training, even before entering upon a technical course. He did not remember that anything of that kind was intimated, or that the securing of both kinds of training was even mentioned. While perhaps it is impracticable—he was sure it is impracticable in most cases, in this day of rush and hurry for getting on in the world—to take a full college course and then the two years required at the least for an engineering course, yet he believed it was practicable to get a good portion of a college course. For instance, boys could be prepared for college in the classical course—and the entrance requirements now in the leading colleges, in the classical course, are almost equal to a full literary college course of former days—so that they would secure a good deal of this, even in their preparatory schools, if directed and encouraged to do so. Therefore, the speaker thought, we ought to be careful, as a Society, not to direct students toward a very narrow course, when many of them could as well take a much broader course of study if they were simply encouraged to do so.

Professor Galbraith said that he quite agreed with Professor Johnson. At the same time he felt that Professor Mendenhall's purpose was to emphasize the educational importance of scientific and technical studies. There has been too much indifference, if not active opposition, on the part of educated men, to the introduction of science teaching into the schools. It is time that this work should be appreciated as it deserves. Naturally the drift of educational tendencies in the past has been in the direction of the humanities and the study of affairs. Attention is now being directed to the study of nature, as distinguished from the study of men. In the ideally educated man the old education will be combined with the new. It would not be wise, however, for the friends of modern methods to lend the weight of their influence to the opposition. Papers of this kind are necessary and are not likely to mislead.

Professor Allen said it seemed to him that in some of the remarks one feature was lost sight of. As he had had something to do with arranging the programme and titles, it might be well to call attention to the fact that the paper dealt with the matter as "training," and it was not altogether a question as to whether the literary course makes a product of a more desirable sort, or whether the scientific engineering education makes a product of a more desirable sort, but as to the efficiency of "training" of the two different qualities of education. It seemed to him that Dr. Mendenhall's paper was very properly directed to that point, and while it might possibly be said that in taking his basis he was careful to take one which was a very complete foundation for the line upon which he argued, it seemed to the speaker that, looking at it as training, it would be very difficult for the author to take any other basis than substantially that. It seemed to him that we are justified in taking up this matter from the point of view of training; and in that light it is fair for us to consider two different kinds of education; and the efficiency of training perhaps means the efficiency in producing men capable of doing good work in thinking and in various other ways. Most of us believe that the proper work of the engineering college is to *train* men. We have laboratories, but the purpose of the laboratories, as many of us think, is to aid in the work of training and education, and not simply to give facility to men in their work. Most of us believe that we want to train men rather than to give them facts, and it seems entirely fair to argue that an engineering education does not give a superior training to a man, so that his ability to think and to do is greater than it would be if his education were not of that particular kind. In a general way, we intend to cover mainly those subjects that a man cannot acquire to advantage away from the engineering college. We are content, in engineering colleges, to leave the acquirement of very much of simple facts to a later date. Having trained our men, we expect them to make use of this training in acquiring facts upon a sound basis. To apply this principle to the work that is done in many of the literary colleges, the speaker thought there is more opportunity for a man to acquire afterward the things that are brought before him in the literary colleges than there is for him to acquire the information and the training that are commonly received in the engineering colleges. As far as a liberal education is concerned in this practical age of ours, the man is badly educated who has no knowledge of what nature has to offer us, no knowledge of the forces that are operating in the world at the present time. To draw an illustration from his own line of work, it seemed to the speaker that a man who knows nothing whatever of railroads and of the work that they have done and are doing for the world, is a very narrow sort of man, and one that cannot claim to be liberally educated and equal to the best duties of citizenship or of general social life. So the speaker felt that we are justified in looking at the school work as a training for the work that is to come afterward; and he was free to say that he believed thoroughly that, on the whole, the scientific, the engineering education, as a matter of training or putting a man into condition so that he is able to do and to think, is far superior to the other style of education. There had been very much said in this society, from time to time, in the direction of what Professor Johnson had said as to the necessity for an extended liberal education in addition to the engineering education that is given. The idea had been advanced that if a man is to succeed in engineering above his fellow men, he must, at the present time, with competition what it is, have his college education first. That idea had been expressed in papers devoted to a considerable extent to that purpose, as well as in discussions in years past. It sounds well, but the speaker was unable to find, in his own observation, any basis for such a statement as a fact. If he were to pick out the men who had been exceptionally successful in engineering work among the graduates of the engineering college that he represented, they would be pretty generally men who had not received a literary college education. Mr. Corthell, in his paper read at the Springfield meeting, referred quite strongly to the value of the college education which he had received. It had always seemed to the speaker that he made a mistake, that he was contrasting a college education as a preparation for engineering, with no education whatever beyond the common schools; it seemed that he was not contrasting a college education supplemented by an engineering education, with an engineering education alone. The speaker believed that if the facts should be investigated to the bottom, it would be found that the man who has a college education only, is in his success in engineering, inferior, on the average, to the man who has the engineering education alone, but that either one of them is superior to the man who entered the work of engineering without any definite school preparation for his work.

Professor Kidwell said, that if he had gathered correctly Professor Allen's meaning, it was that the main point to be considered is the efficiency of the training *per se*, without reference to the men turned out. As efficiency is the ratio of the output to that which is put in, he would like to know how, if he understood Professor Allen's contention, the latter could compute the efficiency at all. The speaker could not see how it was to be done.

Professor Allen said he did not know whether he had made himself clear. It seemed to him that as far as this paper was concerned, the purpose was not to establish the fact as to whether a literary product or an engineering product is the desirable product, but rather to investigate the question as to whether the training given in the classical or so-called literary courses is as efficient in enabling a man to do and to think as the training in the engineering college; and that was the standpoint that the speaker had endeavored to establish in arranging for this paper.

Professor Kidwell said he understood the point made, although it had not been clear to him at the beginning.

Professor Mees said he thought the drift of the discussion shows the exceeding difficulty, even with the exercise of the greatest care in clearing the ground and defining one's position, in making such discussion satisfactory. The author of the paper called attention to the fact that the division of time was, perhaps, indifferently or illogically stated. The speaker thought that was where most of the difficulty arose in this discussion. In the literary course, as here defined, about sixty per cent. is given to what are called literary studies, whereas in the technical course there is given about nineteen per cent. Now, those literary studies, it was said, included languages, together with all those which Professor Johnson characterized as the humanities—logic, psychology, history, and so on. It would seem, then, that it would be fair to inquire as to the extent of overlapping of the nineteen per cent. of literary studies in the technical course and the sixty per cent. of literary studies in the literary course. There is a difference there of forty-one per cent. What does that represent? Does it represent what are called the humanities, or does it represent what in the olden times were called linguistics? He thought that was quite an important point to remember in this discussion. He felt that Professor Johnson was perfectly fair. We live not simply in a material world, but in society. There is no question about that. Therefore, in the analysis of the two courses, it seems just to compare the efficiency of the linguistics. If we confine ourselves to that, he thought the contentions which had been made need not be so strongly emphasized. If a large proportion of that nineteen per cent. is given purely to the humanitarian side, the humanities, as they are called, then, after all, the breadth of the technical course is very considerable, and in that sense he thought Dr. Mendenhall might have made a further division. He thought the Doctor's estimate of the efficiency was largely a matter of the weighing of those two. As a matter of fact, about thirty-three per cent. of the time given to all of the work in the literary course is given to Latin. That, in the early stages, is very largely linguistics; and there comes in the question that is an old story—straw that has been threshed over and over again; yet it should be remembered in the discussion of this question. The speaker thought it desirable to be very careful in defining the basis upon which one might wish to enter on this discussion; he did not think it had been as fully defined in the case of Dr. Mendenhall's paper as it should be to make the discussion fair and just on all sides, which in fact is scarcely ever possible when the author of the paper is not present.

Dr. Murkland said he had tried to find a verification of Dr. Mendenhall's figures, but failed, perhaps because he did not have just the same list. He remembered that in one of the largest technical institutions in the country an examination of the mechanical engineering course resulted something like this: forty-two term-hours devoted to mathematics, one hundred and fifty-two devoted to science and technology, and twenty-three devoted to linguistic studies and the humanities. That left something like nine per cent. devoted to the general studies. It makes a great deal of difference, of course, what institution is taken; but perhaps this matter of average is not so important as it may seem. In the question of the efficiency, he supposed we must consider the purpose. Efficiency in what? Now, the classical college does not prepare the student for any special thing except for life in general. Of course, the technical institution attempts to fit the student for some special vocation. It would hardly be fair to compare the output of the technical institution with that of the law school, or of the medical school, or of the theological school; but the point is, and it seemed to him it is a very important point, that the college and the law school, for example, essay not simply to prepare men for work in the legal profession, but to prepare lawyers and men, and to give for the necessities of general life a common basis of interest; and it is this training for life, with its large common demands, with its necessities for broad human sympathy, that makes all the difference in the world in our conclusion as to the efficiency of any special kind of training. He did not see how any one could doubt that the graduate of a good technical school is more thoroughly trained, trained to greater efficiency in his specialty, than any graduate of any ordinary college is, for anything whatever. The college graduate simply stands at the beginning of things, but he stands side by side with a vast body of men and women who have had a similar training, who have had what the ages agree, rightly or wrongly, to be of great value for the use of the man in life. In this way there is danger that something will be lost to the graduates of our technical schools. The testimony of an individual is not worth very much, but the consensus of individuals who have had a college training and a technical training is perhaps worth a great deal; and he doubted if a man could be found who had added to a college training a professional training in engineering, who would not say that he was convinced, out of his experience, that the only adequate training for the engineer is that which is first collegiate and then professional; and the speaker submitted that this evidence ought to be final, because these are the men that know best. It is impossible to judge of another man's efficiency in this work of life. It can not be said that one of two men, because his name is greater, because his salary is greater, is more efficient than the other, for the question is not simply one of engineering, it is one of living; and there the fundamental content of the man himself is the final basis of decision. What is it that gives a man a greater satisfaction with life, with his work in life, with himself as a unit of life? It certainly is not the lesser education, but the greater.

Professor Allen stated that he did not wish to enter into the discussion too frequently, but there was one point illustrated in his experience that it might be worth while to speak about. He happened to be acquainted with a teacher of languages who was for some years connected with one of the large engineering colleges of the country, and who afterwards was connected with the literary side of one of the large universities. In conversation with him, the speaker was told that in the engineering college the students, as was well known, did not feel such an interest in foreign languages as to lead them to give the most cheerful effort to language study; and as his informant put it, he felt the necessity of coaxing them to that work. After several years in work of that sort he was called to a chair in one of our large universities, and his statement to the speaker was that under the circumstances that prevailed in the latter institution, he was unable to secure the same quality of work from the students as he had been able to get from those in the engineering college, although the latter were so much interested in their professional work that they gave their time to language work only grudgingly. It was only fair to say that there may have been disturbing causes that it was impossible to analyze, that were factors in this condition; but the speaker personally believed it to be true that the work of scientific schools, of engineering schools, does develop in students an earnestness that is not ordinarily produced by the other style of education; and he believed that an important part of the success that was reached by this teacher of languages in the engineering, rather than in the literary college, was due to the fact that this earnestness of purpose and habit of attacking vigorously the work before them, is a part of the training that the speaker wished to call attention to as the subject of this paper, part of the training that is more effectively reached in the engineering college than it is in the literary college. He thought that illustration would at least serve to enforce his point of view, although this isolated case, of course, may have been complicated by facts which might disturb it as an actual and conclusive test. He did not claim that the case cited was conclusive.

Professor Ordway thought the point that Professor Allen had brought out is one of considerable importance. It is not the four years' study, or the five years' study, or whatever it may be, that makes the man, but it is the earnestness with which he studies, and that earnestness depends upon the interest that he takes in his studies. The speaker believed that in the classical colleges generally, the majority of the students do not take so much interest in Latin and Greek as students in technical institutions do in the studies that they have. He had found himself that after graduation students would say they cared nothing more about Latin and Greek, and in fact, a great many of them never look at a Latin or Greek book again. They derive some benefit from studying Latin and Greek, but they do not get the full benefit because they do not take the interest that they should in those studies. Although they do not take that interest they may get through the lessons and they may have good rank. It seemed to the speaker that this is no better than studying for prizes. He thought that studying for prizes does very little good, and he wished the whole system of prizes could be done away with. He thought it a very unfortunate thing that students should be stimulated in a certain direction, and a direction that tends to make them very one-sided. Students who go to technical colleges, he thought, are generally those who go because they wish to go, not because they are sent, while in the case of classical colleges it is the other way; a great many of them go to classical colleges because their fathers went before them and it is considered the respectable thing for them to go also. After entering they may study, they may rank very well, but he thought the majority of them do not care very much for the subjects that they take up. Of course they secure a certain degree of education, they acquire a certain amount of liberalization, by the mere contact with other students and by merely being compelled to study; but of two men of equal ability, one of whom takes an interest in his studies, while the other does not, it will be found, at the end of a four years' course, that the first is worth twice as much as the second. He wished to say in this connection that he thought it worth while to mix these two kinds of studies. It is apparently a good plan to take the college course first and the scientific course afterward; but the trouble is that if one does take an interest in his studies he is apt to get a bias. Many a man who might have made a good engineer, who had the natural qualities, as far as nature can fit a man, for becoming a good engineer, has taken a classical course, his mind thereby being directed the wrong way, his interest in classics turning him aside from what he ought to have done. If a man goes to a classical college first, and is a good student, he is likely to get unduly biased in the direction of the humanities, or of the languages. The modern languages, the speaker thought, do not do very much good, but he was very strongly in favor of the study of both Latin and Greek. Perhaps that was owing to his own early training. He did not believe, however, that those studies should be taken by themselves first, the other studies coming afterwards, but that the studies should be intermixed to a certain extent. He thought it would be found that in some classical schools the teacher influences the student a great deal. He discourages mathematics and everything else except classics, and does all he can to bias the student in that direction, and sometimes a great deal of harm is done in this way. This matter is perhaps better than it used to be, but the speaker knew of one school, the principal of which was a very good classical scholar, and in that school the recitations in mathematics were confined to two per week.

Professor Tyler said he was glad that Professor Ordway had referred to the combination of the different forms of education. While the college course is very often a good beginning for a man that afterward acquires a technical education, it seemed to the speaker that the whole plan lacks unity, and lacks it very badly. There are always, at the institution represented by the speaker, a considerable number of college graduates, and he often had occasion to advise them in planning their work in the college with reference to coming to the Institute afterward. If they had a great deal of latitude in planning their college work they might make the whole scheme of studies fairly harmonious, but too often that latitude did not exist. The speaker's personal preference was rather toward the prolongation of the course in the engineering college beyond the usual period of four years. If the course could be extended to five years, or even to six years, the student would gain a sufficient amount of time to devote to literary studies; and, in the opinion of the speaker, these studies could be given better in the engineering college, in connection with the engineering work, than purely by themselves, just as the engineering studies could be given better in combination with literary studies than alone.

Dr. Murkland said it is a fact that there is a growing tendency toward such a modification of the time-honored college. Three or four years ago, President Eliot laid down a suggestion that the speaker found is being taken up, and that had a good deal of promise in it. It was suggested that the college course might be reduced to practically three years and made up with special reference to later professional training. The suggestion of the gentleman who had just spoken might be considered as something practical along the same line. If we could get five or six years—preferably six, of course—and devote them to turning out engineers, the problem would be practically settled. There really is not much difference of opinion except as to the way by which we can reach the result which seems desirable to all. How can we combine the professional with the general training? In other words, how can we best get at the production of men that shall be experts in their several callings, but shall also be broad-minded, liberally educated men? The speaker's experience and observation agreed thoroughly with the remarks of Secretary Allen, that the studying in technical schools is more earnest and more faithful and less tricky than in the ordinary college. It is easier to trust to the honor of the students in the technical institution, he found, because they are not engaged in a game of intellectual dexterity with their instructors, to see which can get the better of the other, but are working with them for the common object, and that is, as has been said, a very vital matter.

A COURSE IN FRENCH AND GERMAN FOR ENGINEERS.

BY A. N. VAN DAELL.

Professor of Modern Languages, Massachusetts Institute of Technology,
Boston, Mass.

When a young student is admitted into one of our engineering colleges or scientific schools, his mental equipment is, generally speaking, very incomplete. I do not hesitate to say that if he were at that moment entering upon a course that did not fit him to develop his general acquisitions, he could never fairly claim the title of educated man, however great his technical merit might be. Let us examine in detail what he does know. His mathematics are fairly well up; he may be acquainted with the elements of one or two sciences; his English is defective, both his spelling and his grammar being at fault; he has some notions of history and geography, which become somewhat vague when you take him out of his native country; and he has acquired some elementary knowledge of French or German, which must not be submitted to a very severe strain. We need not examine here the important question whether this sum of acquisitions represents all that we could or should expect of preparatory schools; I simply affirm that, taking the masses of students as they come to us, the engineering colleges and scientific schools generally would commit an unpardonable wrong against the welfare of their students, if, accepting students as they do, they left out of their plan of studies the building of a more general education.

This fact has been recognized in America by the greater number of what we may call scientific and engineering *colleges*. I have been told that a German professor has lately taken our higher institutions to task for fulfilling a very plain duty. The critic spoke from a European point of view. If we had to deal with graduates from *Realschulen*, *Gymnasia*, or French *Lycées*, our position would be a very different one, although I could not even then admit that the study of languages and literature should be entirely cast aside. European opinions about our programs are irrelevant, because they are founded on premises entirely at variance with those prevailing on this continent.

German schools have reached a high degree of efficiency in many respects; but that does not mean that we should copy their methods, or even accept their standard as the highest to be attained. I would deny the proposition that it is best, in a four years' course in engineering, even when planned for students with an excellent general preparation, to omit everything that is not of a strictly technical nature, to cut off all connection with the world of literature.

For, after all, schools of all grades have a moral and civic, besides a technical responsibility. They are to provide good engineers; but engineers ought also to be good men and good citizens.

I shall not dwell on the necessity of pursuing the study of English. The man who does not know how to express his ideas correctly in his native language is an intellectual cripple. But I will affirm that nothing is better calculated to broaden the mind of students of science than the study of languages in general, and that among these languages French and German should occupy the most prominent place. I know that I am not advocating a novel cause; the Massachusetts Institute of Technology, to which I have the honor to belong, and many other scientific colleges have given these languages a place on their curricula. But there may not be unanimity of feeling as to their use. And even for all of us, who feel sure that we have been pursuing the right course, it may be well to examine upon what grounds our faith has rested.

The society of which our graduates form a part is a body composed of a great many different elements. It has been modified by influences that have come from distant parts of the world. In the actual state of our civilization, with the daily increasing facility and frequency of intercourse, each nation is influencing the others. In the United States the various nationalities have been brought into immediate contact. And in the Dominion of Canada also, at least two nationalities have become wedded. It is therefore of the utmost importance for every American, if he is to take any part in the solution of the great problems which are agitating our national life, that he should not only understand, but also appreciate and esteem at their just value the contributions of the French thought and art and of German industry and scholarship to the civilization of our time; that his mind should be so disposed that he stands ready to receive whatever advance is made in either of these two great centres. This has great importance from even a technical point of view. I do not say that there can be no good engineer who is not capable of reading what his French and German colleagues have to say on a given question. But I do affirm that both as a man and an engineer, he who can commune directly with the greater part of the world has a considerable advantage over those whose circle is much narrower. Now languages, when properly taught, are the broadest and the most readily accessible gates opening upon that wide world. The study of languages, more especially of French and German, offers also to students whose native tongue is English, many opportunities for strengthening, by a free use of comparison, the power acquired in their own language. In this respect they are to be preferred to Latin, which has only a far more distant connection with their native speech, both intrinsically and on account of the extreme remoteness of ancient thought from the thought of our day. The modern languages are also to be chosen in preference, because they require less time for the acquirement of the ability to read, and so can be more readily retained for future application. This has always seemed to me a point deserving more consideration than it has received. The students who, after a four years' course in a high school, are capable of taking up and enjoying a Latin author of average difficulty, or who feel that they have even a fleeting comprehension of Roman ideas and Roman civilization, are rare indeed—much more so than the students who can read and enjoy a French or a German author during vacation. I meet every year a certain number of our students who do this and intend to continue the practice. Even when this result is not attained I feel sure that the acquaintance and sympathy with modern life is more real than any comprehension of Roman life which can be gained by the perusal of a few books of Cæsar and of Virgil. When, on the other hand, a longer course in Latin and Greek is taken, I own that this last consideration falls to the ground; but how many preparatory students, especially among those who are destined for an engineering course, could give the requisite amount of time for the sufficient mastery of an ancient language? And of those who could give that time, how many actually do so? But modern languages have an undoubted advantage over the ancient languages in a more technical sense, in a way which must arouse the direct interest of future engineers; this technical interest reacts on real literature and brings it nearer. The study of technical works in French and German is a great incentive for many of our young men.

Thus much having been said in justification of the existence of courses in French and German in engineering schools, let us inquire what these courses should be. The first question which meets us is, what have schools done for the preparation in modern languages of students who enter schools of engineering? If I may judge by those who present themselves at the Massachusetts Institute of Technology, the students have been instructed in one language, either French or German, sufficiently to allow us to base our work on theirs. The course at the Institute is four years long, and as that is the usual course throughout the length and breadth of the land, it would be out of place and useless to discuss the question of its duration. After experience which covers a not inconsiderable period, it has also seemed to me that the fourth year of study should be free from everything that takes the students away from their chosen profession. The conclusion lies near that the first year in the technical college should be given to the language which the student presents on entering, and the second and third years to the other language.

This scheme does not seem to me the best conceivable, even under the actual conditions. To the schools belongs naturally and logically whatever is elementary in the general studies. It ought not to be a hardship to ask the schools to provide preparation in the elements of both French and German. The programmes published by the well-known Committee of Ten, and by the similar committees that followed in its wake, are yet in every instructor's memory. These programmes, it is true, have not been adopted by the high schools, for the often-alleged reason that the pupils of the grammar schools do not come to them sufficiently advanced. Teachers in the latter complain of the primary schools, and these of the families. Wherever the fault may be, it is evident to an attentive observer that the system is defective, if under it a pupil, after ten or more years of schooling, cannot be brought to our technical colleges with the elements of two languages. Neither is the plea any longer valid that good teachers of languages cannot be found. There are in every great city a large number of competent teachers of languages who would gladly avail themselves of an opportunity for fixed employment, and the classical colleges graduate every year many young men who are desirous and capable of teaching

French or German. The question has often been asked why the schools should not send us pupils with complete preparation in *one* language; this, it appears, would suit them better, and it might be more economical. As to the economy, this may or may not be true; competent teachers are generally able to teach more than one branch, and if their time is fully occupied, I can hardly understand how their employment could be an additional burden for the generality of schools. The only case of hardship might be found in the remote country places where the number of pupils is so small that one or two teachers undertake all the subjects. The objections to the study of a single language seem to me very grave. First, the proper division of work requires that the more elementary part should be performed in the preparatory schools, and the advanced work in the college. The reason is not in a certain pedantic notion that the teachers in the secondary schools are not as good as in the colleges; in some cases they may be better. But it is a fact that the whole atmosphere of each institution lends itself more readily to the kind of instruction for which it is intended. Then the age of pupils is a matter of importance, because, as it advances, the maturity of the students and their aptitude for lessons of a certain kind increase. The college professors, who deal mainly with advanced students, often fail to appreciate the difficulties of a beginner, while school teachers are mostly lacking in the practice necessary for teaching advanced subjects, and could not well be followed by their class as a whole. Secondly, the study of languages in technical schools does and should differ materially from the study in the classical college, where it can only have a literary or humanitarian side; not that this side is to be neglected in technical schools, but they have a special task of great importance to them, namely, that of introducing the students to technical writings. To require the reading of technical books in preparatory schools is at once unjust and undesirable; unjust to all but the very largest schools, because it necessitates the formation of special divisions; undesirable, because the pupils' technical instruction has not progressed far enough to make them reap the full benefit which their efforts ought to bring. This last disadvantage would be particularly serious in the case of German, on account of the great difficulty of many scientific works written in that language. It is true that the general course might be supplemented by additional reading in the technical schools, but this is also to be deprecated because it would simply involve a loss of time. And time is precious in our four-year courses; it is only by careful calculation and economy that we arrive at satisfactory results; and while the technical departments would justly protest against any encroachment upon the hours allotted to them, most of the professors of languages cannot consent to be burdened with additional tasks.

I have, then, reached the point where we may discuss the employment of the three years considered necessary for the finishing of the language presented at entrance, and the study of the one for which the schools have not provided. The question which every teacher asks himself when the responsibility of determining upon a course of study rests upon him. is, what is the end to be attained by the majority of his students, or, as we may say in our particular case, by every one of them? The answer seems evident to me, as regards colleges of engineering. We must give them, first of all, such a reading knowledge of the languages that the best literature and the best technical works shall be, as far as possible, accessible to them. To cover thoroughly the whole range of the French or German literature in two years, within a limited number of hours, is manifestly impossible. Shall the knowledge be of a more general kind, or shall we specialize? The latter is in itself the better plan, and it is also the one that is most helpful for the technical part of the work. I believe that the course, as the scientific schools give it, should concentrate all its force upon the fluent reading of modern prose. This prose is nearest in form to the spoken language, the easiest to understand, and the best foundation—I should say, the necessary foundation—for all students of language. I have found that the great French classics of the seventeenth century, for instance, when studied in an elementary course, are a great hindrance to rapid progress: the language they use, when mixed up in the student's mind with the sentences of contemporary writers, results in a most extraordinary confusion; the ideas they express are not easily accessible, and necessitate a number of explanations that are most useful in an extended course on literature, but for which we cannot spare the time in the limited number of hours at our disposition. I am sorry to say that preparatory schools are too often great sinners in this respect, possibly under what I consider a mistaken policy on the part of the classical colleges. Candidates for admission to the Institute of Technology are sometimes found to have read several tragedies and yet to be unable to master a few sentences of easy prose. The most extreme case that has come to my notice was that of a student who had read but one book in French, and that was Racine's tragedy of *Athalie.* I know a high school not far from Boston in which the pupils read, as a preparation to elementary examinations, Lessing's *Minna von Barnhelm* and even *Nathan der Weise,* mixed with Scheffel's *Ekkehard,* Storm's *Immensee,* and other works written in everyday language. The mistake committed seems to me as evident as would be that of the master of a grammar school who would give his pupils as a basis for their language lessons sentences from Chaucer, Shakespeare, and the dramatists of the eighteenth century, mixed with selections from Dickens, George Eliot, and Meredith. Of course, it is possible and even easy to choose interesting passages from every one of the authors that I have named; but the object in view is hardly to amuse or interest the pupils during recitation time, but to lay a foundation upon which a solid construction may be raised, either by coming instructors or by the students themselves; and in that case, how can the odd conglomerates that have accumulated in their minds ever be separated again into classified and well ordained distribution? Another abuse against which I feel impelled to protest is the too frequent use of trashy and sentimental novels. Writers that have no recognized standing in France or Germany are chosen without compunction for the class room; hence comes the fatal impression in many youthful minds that such works are the only ones to be found in the literature of these countries. The rich treasures accumulated by French and German historians, biographers, scientists, travelers, and critics, have hardly been touched. Is it not partly on account of this mistake that the advocates of the old languages are still proclaiming that Greek and Latin are our only salvation?

The finishing year of the Institute course in French consists in a careful review of the syntax, and in the reading of some works of Victor Hugo; as, for example, one or two volumes of *Les Misérables*, or *Quatrevingt-treize*, or some other standard book, like De Vigny's *Cinq-Mars;* or a history of Napoleon, made up of connected extracts chosen from memoirs, histories and biographies. It is our intention to treat the history of the Revolution (1789–1795) in the same way.

The scientific treatises in French do not offer any special difficulties to the students who have completed our course, and therefore we give all the time destined for that language to language and literature, properly so called, and to history.

For German, we have found it necessary, in order to obtain the desired proficiency, to begin the scientific reading as early as the second term of the beginning year. This leaves the students entering on German at some disadvantage; but since they are in sections by themselves we have not been willing to give up for their sake whatever might be gained for others. It has also seemed necessary to give to our students scientific text-books composed of extracts taken from German authors, and not adaptations, or still worse, translations from English and American authors into German. While the latter are undoubtedly easier, they fail in their essential object, namely, that of rendering our students familiar with the difficulties they are to meet.

The task of selecting German prose works for our students is not so easy as one might imagine. Novels, dramas and poems have been edited again and again. Only a few of these would suit the purposes which I have tried to indicate. We have finally compromised on three writers: Freytag, Goethe and Heine, each one of whom shows different characteristics. Whether we have chosen wisely is an open question for me.

If I have spoken somewhat at length of our own practice in the Massachusetts Institute of Technology, it is not through any conceit that we have accomplished more than others, but to show you how our ideas have been applied and to profit by your criticism. This may be selfish to a certain extent: and yet, if you can learn from my colleagues and myself how to do or not to do some things, I have thought it only a just return that we should also gain by your experience.

DISCUSSION.

PROFESSOR WERNICKE stated that the courses in French and German that he had been giving to engineering students at the Kentucky College could hardly compare with those of Professor Van Daell, because the speaker's students had no preparation either in German or in French. Therefore, he tried to make up for the deficiency, to some extent, by making his French course more advanced than the German course. In German, it is quite necessary to take the students through the elements of grammar; for students are generally deficient in the elements of grammar, even as far as English is concerned, when they enter college. In German, it is necessary, when they come to declension, to explain what the cases mean; it is quite necessary to speak about the order of words in sentences, and other elementary matters. While these things are perhaps quite as necessary in the case of French, yet if this is made the more advanced study, if the rule of the college is that every student who takes modern languages at all must begin by taking German, then he will have finished this preparation or review in elementary grammar by the time he begins French; in that case he begins French as a sophomore. Then the two years in French probably correspond nearly with the course given by Professor Van Daell, while the first year, in German, would hardly compare with his course in that language. The speaker thought that a great many other colleges are, in this respect, in the same position as his own.

Professor Flather said that the author's remarks on the use of prose as reading matter for teaching French and German, reminded him of the course in German that he had taken, in which the text-book was an ordinary German reader that was used in the public schools in Germany. The preceding class had read a newspaper. The class before that had read from a physical geography.

The German professor thought that the students used a "pony" if the same book were used two years in succession, and he made these frequent changes for that reason. But the whole of the work was prose of the driest sort.

PROFESSOR WERNICKE said he found it quite necessary to change the text-book every year. As for poetry, he never gave that to scientific students, but only in the classical course, where some acquaintance with German literature seems desirable. He usually gave scientific students a course either in Dippold's *Scientific German* or in Hodge's *Scientific German* during the last term of the second year or in the beginning of the third year. The third year was optional with them. He used also a corresponding book in French. He thought, however, that some of the books mentioned, like Racine's *Athalie* and Lessing's *Minna von Barnhelm,* are entirely inappropriate in a course for scientific students.

PROFESSOR ALLEN said that the men that teach languages seem to differ, as to their methods, from teachers of other subjects. A very excellent teacher of languages, as the speaker thought, from whom he had at one time learned something in German, took pains to call the attention of the class to the fact that there was available an excellent free translation of the book that they were reading at the time, and which he was in the habit of using regularly as a preparation for the rendering that he gave the class. On one occasion, through lack of time, the teacher had been unable to use this free translation, and apologized, saying that his translation would probably not be quite so good as usual on that account. His advice was that the members of the class should also use this aid. It was not a literal translation; it was not quite a "pony," perhaps, and yet it was of great assistance in acquiring a vocabulary, without altogether taking away the necessity for the student's doing a considerable amount of work. It is necessary to adopt different methods under different circumstances and with different men. In this particular case, very excellent results were certainly reached in the way described. Of all the teachers that the speaker had had at the Institute when studying there, this teacher of languages was one of two that he should select as the best teachers there.

Professor Wernicke asked whether this conclusion was reached from the point of view of the student or from that of the teacher?

Professor Allen replied that as a teacher he considered him most excellent. He compelled the students to work like beavers.

THE EXTENT TO WHICH METALLURGY SHOULD BE TAUGHT IN MECHANICAL ENGINEERING COURSES.

BY M. E. COOLEY.

Professor of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan.

The materials most largely used by the mechanical engineer are cast-iron, cast-steel, and the bronzes. The strength and perfection of castings depend not only on the pattern-maker and moulder's art, but also on the mixing or founding of the metals. Modern practice has developed much skill in the manipulation of the furnace, the cupola, and the crucible. It is becoming the practice to specify for cast metals with as much care as for the wrought metals. It is not a difficult matter, with skilful workmen and an educated foundryman, to obtain castings that fulfil the requirements of specifications. To accomplish this, the student should have a certain amount of training in the metallurgy of iron and steel and the useful bronzes. He should learn enough of chemistry to enable him to pursue this study of metallurgy advantageously. It is not necessary to make him a metallurgical engineer; that is a separate field. I would recommend that five periods a week for one semester of twenty weeks (two or three hundred hours in class-room and laboratory) be devoted to chemistry, and three hours a week for one semester of twenty weeks, to metallurgy. More than this will deprive other studies of time and unbalance the course.

DISCUSSION.

PROFESSOR ORDWAY thought that the amount of time that the author proposed as appropriate for metallurgy in mechanical engineering courses is much larger than necessary. The speaker thought that one third of that time is sufficient, unless actual practice in the foundry be included; but metallurgy alone could not be advantageously studied to that extent.

PROFESSOR FLATHER inferred that the author did not include foundry work in the sixty periods, and he agreed with Professor Ordway in thinking that that time is too extended for the requirements of an ordinary mechanical engineering course: he thought that one third as much is ample. In his own work, he gave two periods a week for eleven weeks, making twenty-two periods, instead of sixty; and he thought that in that time the students were given some fundamental ideas in regard to the work.

MANUAL TRAINING FOR ARTISANS.

BY CALVIN M. WOODWARD.

Professor of Applied Mechanics, and Dean of the Faculty of Pure Science,
Washington University, St. Louis, Mo.

I assume at the start that Manual Training does not mean either "Manual Labor" or "Trade Training." The distinction is quite generally understood, but it may be well to prevent misunderstanding by pointing out some differences.

Manual training is essentially an educational process. Tools, materials, and processes are studied, analyzed, and mastered, by methods which aim to be systematic and scientific, for the sake of the development of brain and hand through personal contact with forms of matter and manifestations of force, and for no immediate ulterior purpose. The skillful hand and the cultivated mind are a sufficient object. Hence, while the tools and materials are generally those with which industrial establishments are familiar, the methods of instruction and discipline are quite unlike those met in the experience of the ordinary mechanic or craftsman. In a manual training shop the student is never told that he "wants to know too much;" that it is "sufficient for him to do as he is told;" that he will learn "how not to do things" by hard knocks and bitter experience. The student is not kept at repetitions for the purpose of filling orders ; he is not shown where he must be careful and where he may be careless ; his interests are not sacrificed to the business interests of the shop, for he himself is the only product for which teacher and plant and maintenance are provided. The theory and use of tools and the methods of treating materials have been made the subject of as thorough analysis as have mathematics and written language. In the manual training school the fundamental elements are taught as logically as are the elements of algebra or of Latin grammar.

But it will be said in reply to all this that the above methods may be, in fact are, employed in teaching trades, and that I have merely shown how different these methods are from those obtaining in manufacturing establishments and in the old style of apprenticeship. The point is well taken, but the distinction I have made is valuable, for it opens the way between manual training and trade training.

In the teaching of a trade, the elements involved in the particular craft are the only ones admitted into the course; the materials and tools used, the processes employed, the forms or models or exercises produced, are those characteristic of the trade; and all else is excluded. All other tools and materials, all general drawing, all general study of science, mathematics, and literature, are omitted as unessential. The breadth of training is reduced to a minimum, and the intensity of attention to a narrow field is carried to a maximum.

Still more, processes familiar and well understood are repeated many times for the mere purpose of acquiring skill and speed, and of relegating the mental operations involved to the realm of the subconscious or semi-automatic. Moreover, the learner of a trade must learn what the demand of the market is; he must learn the cost of materials and the money value of time and machines. In the manual training school, on the other hand, beyond the scientific study of tools, materials, and processes, the method of procedure is widely different. Instead of a minimum of tools, materials, and processes, a maximum is aimed at. The fundamental principles of all the crafts are introduced. The repetitions which result in skill, speed, and semi-automatic motions are avoided; the student wastes no time in doing things he knows how to do; he never gets beyond intelligent mastery and the ability to go through a process by constant and close attention. The manual training school has little or no concern with the market, nor with the conventional forms in use, nor with the range of current prices. All these are matters which change from year to year, and a knowledge of them at any particular time is of very little value in education.

Finally, the manual training school is full of correlation. The shop, the drawing-room, the science laboratory, the study of algebra, geometry, language, and literature—all combine to strengthen the interest and to stimulate a scholarly zeal and enthusiasm for what is rational, sound, and true.

In the trade school, the question of occupation is settled when the learner enters. In the manual training school, the question of occupation is deliberately put off till the student has completed his course, when he is prepared to make an intelligent choice.

The trade school rarely admits young men before the age of eighteen. The manual training school should graduate the boy when he is eighteen, not with a trade or profession, but admirably fitted to learn one.

The trade school usually concentrates its instruction and practice into the working hours of a single year. The manual training school, with its broad culture in science, mathematics, literature, drawing, and tool-work, extends its instruction over three or four years of school life.

A careful consideration of the above distinctions renders my discussion of the subject "Manual Training for Artisans" very short and simple. Any one can anticipate my opinion. There can be no question of the great general value of manual training to the man who afterwards learns a trade and becomes an artisan. In fact, the learning of a trade ought to be, and generally is, a very simple matter to the graduate of a manual training school; but this warning should not go unheeded: If you wish to make sure of a young man's becoming an artisan, don't send him to a manual training school; for the chances are several to one that he will not become what is ordinarily called an artisan.

I am reminded of a peculiar state of the public mind that existed some eight or ten years ago, when the occupations of the early graduates of the St. Louis Manual Training School were first published. There were but few manual training schools, and the influence of their training was eagerly sought. Dr. W. T. Harris, now United States Commissioner of Education, scanning one of my reports, said facetiously, "There seems to be an alarming tendency in these young men not to become mechanics." Among many educators there was an impression that there must be a failure somewhere. If the graduates of a manual training school did not become mechanics, the school was held to be a failure ; if the graduates of a manual training school did become mechanics, the boys were failures.

I denied both conclusions, and I deny them now. The careers of my graduates, over 600 strong, abundantly refute both verdicts ; and to that list I unhesitatingly refer every inquirer.

When the Philadelphia Manual Training School was organized, the cheerful prediction was made by an educational critic that the graduates would undoubtedly become "a degraded mass of operatives." The records of their two schools, both crowded, show that the graduates go largely into some form of higher education, and that, as a rule, they take high rank in the industrial and social order.

Yet there is a place, and a very important one, for the trade school, and it will be a long time before we outgrow the need of it. There is in every city a large army of young men, from eighteen to twenty years old, who have never received a secondary education, who have no business positions open to them, who, as "hands" in different establishments, earn the wages of unskilled workers, but who would gladly learn trades. The old style of apprenticeship offers no relief and is gradually disappearing; it is such a wretched makeshift that very few apprentices enter, and still fewer stay out their time. The young men of whom I am speaking are, as a rule, too old for the full course of study in the manual training school. For them the "Trade School for Artisans" is a necessity, and in meeting that necessity the trade school has sufficient justification.

But for boys of fourteen, fifteen, and sixteen years of age, that have studied the elements of arithmetic, geography, and English, we should offer a generous course of drawing and tool training with their general academic studies, whatever their ulterior aims. The fancy of a boy, as regards his future occupation, may, and probably will, change with every year of school training; but that should excite neither rebuke nor criticism. The boy that starts with the hope of being an electrician, and comes out with an ambition to be a lawyer, is not to be called fickle; and he that begins with the firm purpose of being a machinist, but graduates with the deliberate aim of being an architect, has probably replaced a groundless whim by an intelligent choice.

My conclusion then is: give a boy manual training, by all means; not because you wish or hope that he may become an artisan, but because you want him to be a whole man and to have an opportunity to make the most of himself, whether he become in the end an artisan or an artist, a follower or a leader, a book-keeper or a general manager, an engine-driver or an engineer, a farmer or a manufacturer.

Permit me, in closing, to say a word as to the danger of too much education. Ever since Alexander Pope proclaimed that "A little learning is a dangerous thing," people have insisted that certain very necessary occupations are incompatible with education, and that we must be careful not to educate too much. If we wish a country boy to remain a farmer, we must educate him cautiously and by himself, lest he be educated away from the farm. So if we wish a boy to become a plumber or a steam-fitter we must be very careful or he will become a sanitary engineer or a mechanical engineer.

Well, suppose your educated boy does step to a plane that is intellectually and socially higher, is there any cause for regret, or should there be a sense of failure? Suppose the boy is your son or your brother, do you still regret? Or do you regret such results only when the boy is the son or brother of an uneducated day laborer? In my judgment no one can ever be hurt by thorough, well-balanced education and training. Plenty of people suffer from ignorance and lack of education. If education ever makes a man foolish and helpless, it is because his education has been unbalanced; because he has been fed on prejudices, traditions, and conventionalities; not because he has learned how to apply his knowledge of history, mathematics, and science to the problems and duties of real life. If you make a boy believe and feel that it is not genteel to take a tool in his hand, he will not become a farmer or a mechanic. If on the other hand you teach him that the skilled hand is an honor and a fit companion to the cultured mind, he will cheerfully become an artisan, and he will remain one just as long as the world will let him. The world will load him with responsibilities according to its needs and his ability, and if in the end he becomes a superintendent or a general manager, it will be because he is in demand as such. The only people that will block his path and depreciate his abilities are those ill-taught individuals who fancy that unskilled hands and an ignorance of practical arts are the best evidence of a cultivated brain.*

---

* This paper and the following one were discussed together : see page 284. EDITORS.

THE MANUAL TRAINING HIGH SCHOOL.

BY THOMAS W. MATHER.

Principal of the Boardman Manual Training High School, New Haven, Conn.

The object of this paper is to point out the relation which should exist between the different departments of a manual training high school, rather than to discuss manual work by itself.

Many of these schools have sprung up throughout the country, and in many other schools manual work, in one form or another, has been introduced. Indeed, the time is probably not far distant when it will generally become a feature in all schools of the grammar grade.

The character of the manual work done in many cases, perhaps in the majority of them, is determined by local considerations, by expense of equipment and maintenance, or by shop facilities; but even when the authorities in charge have an option, there are quite wide differences both in theory and in practice. There has been, however, until lately, substantial agreement as to the nature of the studies to be followed in connection with the manual work; perhaps it would be better to say that while manual work has been added to the curriculum of the modern high school, no essential change has been made in the nature of the academic work. The studies remain essentially what they were thirty years ago; they are determined primarily by college requirements for entrance examinations. Even when but a small fraction of those graduating from the high school pass on to higher intellectual work, the same course of instruction is given.

In cases where it is possible for the pupil to enter a college or a school of technology, there is little to criticise in this preparatory work. Indeed, the lower school is but a part of the higher one, and is necessarily bound by its requirements. There may be a difference of opinion as to the value of these; as, for example, three years' preparation in Latin for a school of engineering, in preference to German or French; but usually the high school must accept what the college prescribes.

In what follows, therefore, we will refer specifically to schools from which the great majority pass directly into the active work of life—schools especially intended to instruct their pupils in those things most likely to fit for this work, regardless of what is best for the few who can afford or find time to go further.

The feeling has been growing rapidly, among those in charge of manual training schools, that important changes should be made, that what is best for one is not necessarily best for another, and that the manual training high school should be something more than a college preparatory high school with a shop attachment. We can be well content to allow the higher institution to dictate what its entering pupils should know, but let us not, while preparing these, sacrifice the education of those less fortunate.

There should be, therefore, two courses of instruction open to both boys and girls; the first preparatory for college and meeting fully its requirements; the second intended for those whose schooling must end upon graduation day. We shall assume each course to extend over four years, and that the school day is divided into six working periods of about three quarters of an hour each.

Let us now consider some of the more important differences which might profitably exist between these courses.

The study of pure mathematics has hitherto usually extended throughout the entire high school course, a daily period being given to it; and the pupil entering, say the Yale Scientific School, is expected to pass a rigid examination in all of algebra as far as the general theory of equations, all of plane and solid geometry as given in Phillips and Fisher, and lane trigonometry through the solution of oblique triangles.

Can we not employ some of this time to better advantage with those not intending to go to Yale?

What should we think of a man who had spent four years in preparing an elaborate chest of tools, many useful, others purely ornamental, and had then contentedly laid them aside to rust? Does he not resemble the boy who spends an equal time in acquiring mathematical tools, and then, unskilled in their practical use and unable to give more time, is forced to lay them aside to rust? Would it not be vastly better to give him a less complete assortment, leaving out the purely ornamental, and then teach him to use what he has, to apply them, so that in after life he may keep them bright and clean?

Many of those present will agree that, leaving out of account mental discipline, there is little of practical value, even to students in schools of technology, in much that is found in the latter part of algebra. The progressions, permutations, and combinations, the binomial theorem applied to fractional and negative exponents, continued fractions, and the method of undetermined coefficients are interesting and ornamental, but are they worth the months that the high school boy gives to learning them? Again can we not replace his terror, known as solid and spherical geometry, by something he will not forget immediately after graduation?

In answer to this we are usually met by the time-honored words, "mental discipline," meaning that in these particular studies there is a mysterious quality making them valuable above all others for developing and training the mind; that by making a boy learn that which he dislikes and in which he sees no practical value, mental growth and strength will be correspondingly increased.

We of the new school are not disposed to admit this. We think the value of any study depends largely upon the degree of interest the pupil may be made to take in it; that without interest, mental impressions are much less likely to last; and that the degree of interest is usually decidedly greater if the practical bearings of the subject taught are obvious.

At the Boardman Manual Training High School we have, therefore, cut out the mathematical exercises noted, together with a few others, such as difficult cases of least common multiple and greatest common divisor, square and cube roots of polynomials, troublesome solutions in quadratics, and series.

In this way the course in pure mathematics has been shortened to a daily period for two years, and, as a substitute during the remaining two, we have introduced the application of mathematics to elementary and applied mechanics.

The importance of these studies to a boy entering any of the mechanical pursuits of life can hardly be over estimated. He should become familiar with the forces controlled or in operation about us. They enter more or less into every man's life. It is idle to expect him to gain this knowledge after leaving school, for in the struggle for a living he rarely has either time or inclination; neither is he in a position to learn readily without expert teaching. Let us, while we have the chance, teach him to use his mathematical tools, and give to them a value not measured simply by mental discipline, but extending into the practical occupations of after life. In our opinion, the mental development will in this way prove much more marked and lasting.

During the third year we devote a period every day to elementary mechanics, of the same kind although not as advanced as that usually given in the universities. It should include a thorough comprehension of what is meant by force, work, power, energy, velocity and acceleration; the doctrine of the conservation of energy; the composition and the resolution of forces and of velocities; the force necessary to produce acceleration; and the energy contained in a rotating mass. The boy should become familiar with the elementary principles of mechanism; with the laws governing friction; with elementary hydraulics; and he should be taught to measure power.

During the fourth year an equal time has been given to applied mechanics, including heat and heat engines, strength of materials, and stresses produced in structures.

During the past year we have carried a class of boys through these subjects most successfully, and can testify to the enthusiasm and interest displayed. They should be taught experimentally. Just as we have our chemical, physical, botanical, biological, and electrical laboratories, so there should be one devoted to experimental mechanics. Much can be done with inexpensive apparatus, and the production of even the more elaborate can profitably be made a part of the manual work, in this way gradually building up a course of far-reaching value.

In the manual training high school, much prominence undoubtedly should be given to the so-called science studies—physical geography, geology, botany, chemistry, physics, electricity, and biology. At the Boardman School we have given to these subjects four periods each week for the entire course. It is unnecessary to speak in detail of methods of instruction. All receive laboratory treatment, and constant use will be made of the electric lantern, especially in the study of physical geography, geology, botany, and biology, the school being provided with facilities for making slides. To electricity is given a year by itself, the aim being to give, as far as possible, a commercial knowledge of the subject. The boy should be taught to wire buildings properly, to use measuring instruments, and to understand the construction and care of dynamos and motors. The field is a very broad one, but, properly started, some will undoubtedly find a vocation in it, and perhaps be tempted to study more and advance far.

Much time should also be given to mechanical and free-hand drawing. The direct care of the former should unquestionably be in the hands of a man who has had considerable experience as a designer and draughtsman. Too often it is turned over to a young graduate, who, while understanding the principles of projection, knows little of details of construction. As with pure mathematics, drawing should be looked upon as a tool or method, which the pupil must be taught to use.

We have found the first year sufficient for learning the principles. No time should be wasted in special exercises for teaching the use of instruments. This comes readily enough without them. After the first year we give the entire time to constructional work, in which the drawing is but a means for expressing some definite idea in design. This plan has resulted in a remarkable increase in interest and technical skill.

Too little attention has usually been given in high schools to what goes under the head of free-hand drawing. Aside from leading to an appreciation of the beautiful and artistic, it affords an admirable training for the hand and eye, and it has a decided practical value.

We give little time to development of the so-called type forms. While plausible in theory, there is a deadly lack of interest, and pupils upon entering are immediately set at work upon studies from the pose and groups of objects, much care being given to artistic spacing and arrangement. We have given much prominence to decorative design, such as book covers, wall papers, floor coverings, dress patterns, stained windows, and initial letters. Ornamental designs of every description for forgings, dresses, wood carvings, Venetian iron work, clay modeling, etc., originate or are developed here, and illustrations for the school paper, for English compositions, posters, and advertisements, lend variety and stimulate interest. No other department can be so completely correlated with the others in a school.

In order that a manual training high school may be a success, it is, in our opinion, of supreme importance that it be of as high grade on the academic side as any competing school. An hour and a half every day can be given to manual work without necessarily interfering at all with that due to the class-room and laboratory. Indeed, it will be found that the interest created in the one usually extends to the other, and that more and better work can be gained from pupils on this account. The public, partly on account of the unfortunate name "manual training" attached to these schools, is inclined to look upon manual work as the essential and most important element in the education given, and to infer that if a boy is to gain a good academic training he should go elsewhere. Unless this idea can be dispelled, a public high school of this character can seldom be maintained successfully; for the feeling is strong that while manual dexterity and a knowledge of mechanical processes are important, the boy's or the girl's schooling should go to the development and training of the brain, and that, if necessary, the manual training should be sacrificed in favor of the mental training. Accordingly, our academic work should be made as strong and thorough as the best. It is unnecessary to go into details; but to the study of English and English history, the modern languages, mathematics and the sciences, we should especially bend our energies, introducing new methods, paying not too much reverence to antiquity, but stimulating the work in every way.

At the Boardman School, the printing department has proved a most valuable adjunct to the course in English. Excellence in composition is rewarded by publication of the exercise in the monthly school paper. This paper, while edited by the pupils, is officially a part of the school work. Proof containing predetermined and other errors must be corrected by the student. Literary passages not contained in the text-books can be cheaply reproduced, records of experimental work in the laboratories can be printed; and, in general, the ability to give permanent expression to thought and experience has added decidedly to the interest.

The character of the manual work, as before stated, must depend largely upon local considerations, upon the facilities offered, and upon the ability of the instructors employed. The order of the work is similarly affected, but by general consent wood work is assigned to the first year and machine tool work to the last; the other industries, forging, pattern making, molding, sheet metal work, plumbing, etc., filling in the intermediate time. The order in which they come does not appear to be especially important. The girls' work is less distinct in character and cannot be so readily limited in time. At the Boardman School, for example, both domestic science and sewing, in their various branches, continue throughout the entire course, while wood carving, clay modeling, and Venetian iron work are variously distributed.

Typesetting and printing are at present given only to those that, for one reason or another, are unable to do the other manual work satisfactorily.

It is unnecessary and would be unprofitable to enter into the details of the manual work. No two competent instructors give exactly the same exercises, nor, indeed, does any instructor continue the same exercises year after year.

Until recently, the so-called Russian system has been almost universally adopted, not only in high schools, but also in schools of technology. The system consists of sets of exercises designed to illustrate progressively uses of tools and to lead to greater skill, the product in itself being usually valueless. But a feeling that the system should be decidedly modified has been steadily growing and found emphatic expression, with but little opposition, at the recent meeting of the American Manual Training Association. There has been a lack of sustained interest on the part of pupils, and carelessness and indifference as to the quality of their work. The system has left out of account the boy's nature, his love to accomplish something obviously worth doing, to produce something he can take home and use. While certain of these exercises are necessary, we are convinced that the number should be greatly reduced, and, as far as possible, every exercise should be on something of value in itself. At the Boardman School the change from the old to the new line of work has been attended with a marked increase in interest and a decided improvement in quality of work. Indeed, the interest was so great during the past year that it became necessary to prevent pupils, both boys and girls, from giving more outside time to the shop than could be spared from other studies.

When practicable, the project should be the work of one pupil, to whom it should belong when completed; otherwise it should be something needed by the school and should belong to it. In every case, accuracy should be an absolute requirement, everything made being subject to inspection, and not being accepted unless it reaches the required standard. "It must pass inspection," means much to a boy who knows what it is for and realizes the necessity.

The manual work should be forced into close relation with all the other work done in the school, and this can be brought about most readily through project pieces. For example, a piece of apparatus is required for the electrical, the physical, or the mechanical laboratory. The design and calculations are made in the laboratory, the detail drawings in the mechanical drawing room. These pass at the pattern shop, into the hands of another set of boys, and the completed patterns are sent to the foundry. The castings when finished are sent to the machine shop, where the steel, brass, and wrought iron parts have, perhaps, already been completed. Finally, the machine is assembled, and is then sent back to the department where it originated. Different classes have had a hand in its construction. The whole school knows about it and is interested. A free-hand sketch, with description possibly appears in the school journal, and the project remains for the instruction of succeeding classes for years after.

This plan is now being carried out at the Boardman School, and results already obtained indicate a pronounced success.

It has been our aim to prove that the manual training school should be something more than an ordinary academic high school with a shop feature added, especially when intended for boys and girls whose schooling must end upon graduation day; and we have suggested some of the changes which might profitably be made. Others will no doubt come with further experience. Let us hold to what is good in the old, but not sacrifice the education of the many for the benefit of the few.

The manual training school, or as it may preferably be called, the scientific high school, aims to educate not only the head, but also the hand and the eye, to teach the things most likely to be of use in after life, to give a broad, accurate conception of the laws governing the world we live in, and knowledge of its history and life, and to stimulate appreciation of what is good in art and literature. The aim of all schools is essentially the same, but we have been given new tools, are employing new methods, and hope for better results than have hitherto been attained.

DISCUSSION.

PROFESSOR JOHNSON inquired how long the Boardman School had been in successful operation.

PROFESSOR TYLER said he thought it was not less than four or five years.

PROFESSOR FLATHER said it was his impression that it was about four years.

SECRETARY ALLEN said that Mr. Mather had been the President of the Manual Training Association during the preceding two years, so that what he said came with something like official authority.

PROFESSOR JOHNSON said that he was sorry Professor Woodward was not present to take part in the discussion of the second paper. The speaker was connected with the same institution as Professor Woodward, and knew something about the first manual training school that was established. The name originated with Professor Woodward, and it was still regarded by that gentleman as a rather fortunate name. The speaker had been exceedingly pleased with the second paper. He thought it gave a more favorable prospect for the continued operation of these schools than any other he had had the pleasure of reading or hearing. In St. Louis there was only a single course, with some slight variations; but it was practically a single course for three years, and it was supposed to fit the boys for the engineering courses at Washington University or other engineering college, or to finish their education, as the case might be. Many boys did not decide until after they had been graduated, whether they would go further or not. He believed that Professor Woodward's argument in favor of the single course was just this: that the boy is not prepared to decide in advance whether to go further or not. The speaker thought it a very sound argument. At the same time it is unfortunate, in that it forces the school to have but a single course for two different purposes. In the New Haven school, the speaker understood, they force the boy to decide in advance whether or not to prepare for college; and the respective courses seem to be very different. He believed that the rest of the faculty at Washington University had pretty well decided that question since they had had large experience with these boys; and he thought that half their engineering students came from their own manual training school. But they thought it unfortunate that the course should be shaped for those two ends. If it were to be arranged especially for the college, they could point to many things in it that seemed unsuited to such a course. He believed the last paper to be a valuable one, in that it shows that such schools are likely to become common. If the engineering schools could furnish facilities for manual training as far as might seem to be necessary to the engineer, it does not seem that a manual training preparation for college is really essential to an engineering course. In the engineering school of Washington University, students who do not come up through the manual training school are privileged, or forced, to take these manual exercises as extras, to a limited extent. It is a sort of condition upon their course, the courses being laid out especially for those who have had those opportunities. The speaker did not now feel, however, that those exercises are as essential to the engineer as he had thought them a few years ago; and he believed that this New Haven experiment marks the way to the most successful combination of manual exercises with high school work.

Professor Ordway said he was glad that the paper last read shows that there is a tendency to do what he himself advocated from the first; that is, to abandon the Russian system in favor of the system of making complete articles. The speaker had had something to do with the first manual training school that was started in the country, namely, the School of Mechanic Arts of the Massachusetts Institute of Technology. The system inaugurated there was adapted from the Russian system, and a good many of the models used were made in the school at Moscow. Under the Russian system parts only are made; for instance, instead of making a complete box, the student makes two sides of a box; or, if it is a dovetailed box, he dovetails only one corner, not finishing the box. It had always seemed to the speaker, and the experience of these teachers would appear to confirm it, that it is very much more interesting to the student to make complete articles, and that better mental discipline results from this method; because, if the student makes a complete article, he can himself see whether it is what it should be. If he makes a single part, he has to depend in some measure on the judgment of the teacher. For instance, if he makes a box that will not stand square on the floor, he can see at once that it is not true. If he makes only a single part of it, he can not see its faults so well. It is very important to make the work as interesting as possible to the student, so that he will pursue it with zeal; and this can be accomplished with certainty by having him make articles that he can be allowed to keep. The speaker's own rule concerning this work had always been to make nothing for show primarily, but to give the student everything that he made, with the reservation that a part of his work, selected by lot, should remain the property of the school; but generally he took away, if he chose, everything that he made. The speaker had found that students are very proud of the things they make; and he believed that in the construction of useful articles they learn a great deal that they would not learn by making mere parts, which are in many cases forced exercises, and in which they do not take so much interest. The speaker said, further, that he believed it would be very useful to have these manual training schools, or mechanic arts schools, in connection with high schools, or, rather, to have independent schools of this kind all over the country. If that were done, it would save our engineering colleges a good deal of time. He believed that all students should have some training of this kind, for they can certainly do better in the laboratory, they can do better in almost any sphere of life, if they learn to use their hands than if they do not. If boys could obtain this training before entering the engineering college, beginning perhaps at the age of twelve, by the time they leave the engineering college they would have a pretty complete system both of drawing and of manual training, which would prepare them very much better for entering on their engineering work; and this manual training preparation might be given by the high school without detracting very much from the ordinary curriculum. The interest in manual training work is so great that boys would do that in addition to the usual high school work.

President Eddy said that the part of this last paper that seemed to him most remarkable was that relating to training the high school student into a working knowledge of the fundamental principles of mechanics. The speaker had some doubt as to the general practicability of that, and wished that he might hear expert opinions on the question. In view of the fact that it is very difficult to do it in the college, it seems almost an impossibility to do it in the high school.

Professor Allen thought the paper mentioned the fact that it is considered desirable to make the course mainly experimental rather than theoretical.

Professor Waldo said that these two papers are rather remarkable in several particulars. They are in important respects diametrically opposed to each other; the first paper, by a gentleman who is generally acknowledged as the originator of the idea of the manual training school in the United States, setting forth, in the most emphatic way, some principles upon which those schools should be established, and the next paper giving the practice of to-day in these manual training schools and setting forth the principles upon which the manual training school of to-day should be established, diametrically opposed to the methods set forth by the originator of the system. It seemed to the speaker that nothing could be more instructive than these two papers, which bring together the theory of the originator of the system and the practice as it has necessarily developed in the growth of the schools themselves. He did not think that the Boardman school was the first to discover the necessity of departing from the principles laid down by the originator of the manual training schools. It had been the good fortune of the speaker to visit one or two manual training schools in other parts of the country not a great while ago, and he found in operation substantially the same things as were mentioned here as occurring in the Boardman Manual Training School; he learned that it had been found impracticable to continue in what might be called classical manual training, as distinguished from scientific or professional manual training. It might, perhaps, be difficult to carry that analogy all the way through; but the distinction between these two things had been recognized in the various manual training schools, and he thought the most progressive ones were proceeding on the principle of manufacturing something useful. This Russian bugbear which had been mentioned, it seemed to him, carries us a good way back in this question of manual training, and carries us to a story that is not generally thoroughly understood. The Russian system came in with the Russian exhibit at the Centennial Exposition; it was supposed that the system was fully shown in that exhibit, and the so-called Russian systems developed upon that basis were evidently supposed to embody all the features of the original. But some gentlemen who were engaged in the development of this kind of education, and with whom the speaker had been intimately associated, had visited the schools in Russia and had discovered that only a half-truth had been brought into our country. The Russian technical schools, which are indeed among the best that exist anywhere, are based upon a six years' course instead of four. The student spends the first year or two of the course, or perhaps three years, in making typical forms; he then goes on to the construction of full-sized machinery, and is made familiar with manufacturing processes, and with the design and construction of special machines. Thus he is brought into intimate contact, not merely with typical forms, but with all that is full and complete in machine work and design. So our Russian system, which stops with the construction of a few typical forms, is not the Russian system at all; and we are coming to a much more sensible view of the matter, to a view that is perhaps wholly American in its development, but which brings us very much nearer the real Russian system than we have been before.

Professor Ordway wished to correct what he thought was a misunderstanding on the part of many. The introduction of this Russian system into the United States was due to President John D. Runkle, of the Massachusetts Institute of Technology, who, observing the Russian specimens at the Centennial Exposition, took measures at once to start the Mechanic Arts School in which this system was introduced. He gave the name "Russian" to the system of the school, although the students in the Russian schools do go into the manufacture of machinery after their preparatory work. There was another system that was in use at that time, and that had been in use for years before, the Sloyd system, as it is called in English. This system originated in Finland; but being introduced into the common schools in Sweden, it grew gradually until about 1872, when it was introduced into the schools over almost the whole of Sweden; and thus it might perhaps be called the Swedish system. Under this system, the articles made were mainly those that are of use in the household. The students make, not parts, but complete articles. Our American system—and it might be justly called that, the speaker thought—is neither the one system nor the other, but it is, in his opinion, nearer to the Swedish system. He had never been aware of the system until he went to Sweden, in 1888. He found the system in full operation there. He had not heard of it before; and he thought the people in Europe generally had not heard of it before, because at that time he had met some gentlemen in England who were appointed on a Parliamentary Commission to examine into industrial education, and they seemed to know nothing about the Swedish system, although it was right at hand. The speaker saw it in operation at Stockholm, and afterward visited the fountain head of the work at Nääs, in Sweden. He thought it was hardly fair to President Runkle, who had labored very hard in introducing this system into the country, to ignore him completely in connection with the subject. He certainly deserved a great deal of credit for his work in that direction; he did a great deal of work to bring it about, and his work was successful.

Professor R. C. Carpenter said he had been very much interested in the papers read, and it seemed to him that the two were hardly antagonistic in their principles. At least his impression was that one merely states general principles which should govern trade schools, while the other describes the application of certain principles or methods which had been found necessary and expedient under other conditions. He did not see that there is necessarily any clashing of the two ideas. But, with reference to the latter paper, it struck him that the principles described therein as new or novel had been put into practice several years before. He remembered visiting, at least twelve years ago, the Chicago Manual Training School, in which the method carried out was almost identical in principle with that described as applied in the Boardman school. There were in the Chicago school a certain number of exercises, each as complete as possible, and illustrative of some principle or method of construction, which were first mastered; then the students were put to work, not on articles to be sold, but on useful apparatus, to become part of the plant of the institution. For instance, the students built their own forges and their own engine, and did a great deal of other useful work. The speaker was quite certain that the same system had been continued in that school to the present time. From this statement it seems this principle is not altogether new as a matter of practice. The speaker had for a good many years had opportunity to observe methods of teaching manual training in connection with college courses. Of course such students are different in the respect that they are more advanced than those in manual training schools; but after all, the methods of teaching and the results obtained are to a great extent similar. During this time he had seen a good deal of change in methods. It struck him that the tendency in college instruction in manual training had been to change toward the plan laid down in the last paper, that of dropping the model system as much as possible, using it only as far as is strictly necessary to give the students knowledge of the use of tools, and giving advanced training by building, as far as possible, useful apparatus, not designed for the market, but to be used in the college and to form a part of the college plant. He thought that in the case of the colleges the results of this plan had proved very beneficial. The students had taken more interest in their work as its usefulness was increased, and on the whole the shop exercises had increased in value and students had become better workmen.

Professor Waldo said that the remarks of Professor Ordway explained what the speaker meant by the system known as the Russian, that originated with our Centennial Exposition, was carried to Boston, and spread from there; but previously to that time Charles O. Thompson, who organized the Worcester Polytechnic Institute, and who had made journeys through Russia, had started that Institute on a diametrically opposite basis. If the educational literature of that day be looked into, especially such as was published by our Government, it will be seen that President Thompson advocated from the first the idea of the manufacture of useful things and started the

Worcester Institute on that basis, and that from that place there spread a sort of revolt against the so-called Russian system. It will be found, the speaker believed, that the method in vogue throughout our technical colleges and our large manual training schools, so called, is very much more in line with what President Thompson brought back from Russia and established at Worcester, modifying it somewhat to make an American system, than with the system as it was introduced at Boston. And of course we must distinguish pretty carefully between these schools. A manual training school is not a trade school; the two are entirely distinct. Our manual training schools are becoming what may be called junior technical schools. The speaker thought that to be the tendency, and that they will ultimately come into that form.

Professor Ordway remarked that the fundamental ideas of the two schools, the Worcester school and that at Boston, are totally different. In the former school the aim is to make articles for sale, whereas, at the Institute of Technology it had been laid down as a principle from which there should be no departure, that nothing should be made for sale, that nothing should be made with reference to the market at all.

THE AGRICULTURAL COLLEGE IN ITS RELATION TO ENGINEERING EDUCATION.

BY CHARLES S. MURKLAND.

President of the New Hampshire College of Agriculture and the Mechanic Arts, Durham, N. H.

Your secretary informs me that I must not use more than fifteen minutes of your time. The limitation is welcome, inasmuch as it enables me to present a simple statement of the facts, with very little elaboration.

For this discussion, a precise definition of "The Agricultural College" is impossible, because there are so many varieties to which the name is applied. There seems to be but one course to pursue: to consider every institution, eligible to membership in the American Association of Agricultural Colleges and Experiment Stations, to be fairly within the scope of this paper. This I have done, although the list includes at least one institution in which there is no special reference to agriculture, and excludes others, like Harvard, where there are agricultural courses.

In the first place the name "Agricultural College" is never definitely characteristic, is generally a misnomer, and is therefore always misleading. In the few institutions properly called by this name, there is no relation with engineering education. There are technical institutions where instruction is given in engineering, to which the name is sometimes applied, but which might as well be called by any one of several other names. If these institutions were called chemical colleges, or electrical colleges, or mechanical colleges, or surveying colleges, the result would not be more misleading than when they are called agricultural colleges.

These facts are of some importance to the cause of engineering education. The name given to an institution affects its possible constituency. It is not easy to make a boy with a marked mechanical tendency see what he is apt to gain by going to a college which calls itself, or suffers itself to be called, agricultural. Those who are interested in engineering education should not unnecessarily prejudice their cause by perpetuating this blundering nomenclature.

Among the colleges to which this name is thoughtlessly applied, there is no uniformity as to the kind or the amount of instruction immediately pertaining to engineering. The differences concern the starting-point, the process, and the conclusion: in other words, entrance requirements, courses of study, and degrees.

In the association just mentioned, a committee was appointed to make a careful study of the entrance requirements of these institutions, with a view to recommending some standard. The committee found it necessary to recommend two sets of requirements, one for immediate use, and one for the future. This latter set of requirements was not in any sense ideal: is was a manifest, and not altogether satisfactory, compromise between the ideal and the actual, with large concessions to the actual. The report of the committee, with recommendation that the suggestions be adopted by the colleges belonging to the association, was accepted, at the meeting at Washington, in November, 1896.

I may add that, through the kindness of Professor Tyler, advance sheets of the report of the committee of this Society dealing with the same problem, were submitted to the committee of the colleges, and were of great value in confirming the conclusions already reached. Strangely enough, or naturally enough, the two reports, independently framed by the two committes, were practically identical in the body of their recommendations. The entrance requirements suggested by your committee are a little more exacting, and are therefore, by so much, to be preferred.

As to the course of study, there cannot be a definite standard without some agreement as to the starting-point. And in speaking of a standard course of study, I do not wish to provoke the ready and familiar discussion as to the desirability of detailed uniformity. Upon this I suppose we all agree: the opportunity given to the student in engineering in one place should be fairly equal to the opportunity given in any other place. It should make possible a proximate equality of attainment in mental power and furnishing. Whether there should be the same kind of furnishing, or even the same kind of power, is another and a less certain matter. Concretely, it is desirable that the degree of M.E., or E.E., or any kindred degree, should have some definite meaning, and a meaning more definite than merely that of graduation from some kind of institution. And that presupposes equivalence in courses of study and in entrance requirements. The colleges under discussion have taken the first step towards this consummation. But it is only a first step.

Given the fair starting point, the later course of study has its grade thereby determined, within narrow limits. An investigation of the facts confirms this statement. The facts are not easy to get at. Circulars of inquiry do not always call out satisfactory replies. Catalogues are not always so constructed as to supply detailed information as to courses of study; perhaps they are not always meant to give such information. But from a collation of the facts presented in the catalogues of these institutions, I find that while there are many differences, these differences are not so great as might be expected. The range of variation may be indicated, roughly, by saying that some of these institutions place calculus in the senior year, while others place the method of least squares in the junior year. Here is a difference which amounts to about two years' work, possibly less. But even this difference is not so great as it appears; for the institution that places calculus in the senior year is at least guiltless of the iniquity of professing to fashion mechanical engineers, or electrical engineers, by four years' work, with only the material furnished by the secondary schools. The necessity for postgraduate work is so obvious that the Bachelor of Science, or Bachelor of Engineering, is likely to be as fully equipped as his neighbor, when he wins his full degree in engineering at some other place.

It is to be remembered, as urged in a paper presented yesterday, that these institutions are not separate technical colleges, simply, but are integral parts of the educational system of our country. Perhaps we have no thoroughly elaborated educational system; but, at any rate, these colleges have helped to reduce the inchoate educational fragments into something like a system. And in this connection their function with relation to engineering education is most clearly defined. These colleges by themselves are essentially local, perhaps provincial. That is their virtue, and by reason of it they make coherent parts of a system. They must connect closely with the preparatory schools of their own neighborhoods. And they must, at least they do, aim at supplying the technical demands of their several sections. The state college of the East does not primarily interest itself in mining, nor in irrigation. The state college of the South lacks the public schools of the North, and it has its own problems to study. North and South, East and West, the state college advances education in engineering, and not least in those states where the actual courses of study are lowest in grade. Considered as a thing by itself, the college of this or that state may easily be criticised for the elementary nature of its work in engineering. But such criticism is perverted by faulty perspective. The institution must be estimated by its fitness for its environment; by its efficiency as a local factor in the educational system; most of all, perhaps by its manifest tendency. If these colleges do not turn out many competent engineers, they do link engineering with the training given in the common schools of the whole country; and that is no insignificant function.

But this provincialism is accidental and temporary, not essential and final. Part of the specific function of the engineering department of these colleges is to elevate the secondary schools, and to modify their teaching vitally. The movement of educational demand is from above downwards, not from below upwards. The college forces its demand upon the secondary school, as the larger school of affairs keeps its constant leverage upon the college. Nowhere in the college is the uplift of the demand of practical life more strongly, more immediately felt, than in the department of engineering. These departments, as they respond to the demand, must draw the secondary schools after them; not simply by way of higher standard, but also by way of specific preparation. And the heart of the whole matter is here. Just what do the engineering courses demand, or what would they demand if they had only to ask and to receive? Is any man able to answer, to-day, without fear that he must revise his answer to-morrow? I think not. And this very uncertainty indicates the fact that the function of the college, in this respect, is to continue the development of our educational system, by the elevation and modification of the secondary schools.

As to degrees: these colleges do not commonly confer the full degrees in engineering at the end of the four years' course, for the degree of Bachelor of Engineering is distinctively preliminary. Most of them do not confer such degrees at all. This enforces the conclusion that the point of stress must be that of entrance. If the degree of Mechanical Engineer, for example, were commonly given by these institutions, it would be possible to reach some approximate determination as to what that degree should represent. At present the simplest thing would be to decide that it should stand for so many years' study, roughly outlined, following a certain standard of preparation. And I am inclined to think that any suggestion of this kind, from this Society, would be welcomed by the American Association of Agricultural Colleges and Experiment Stations, and would be put into practice as widely as possible.

There is nothing for me to say as to the quality of the work in engineering in these colleges. But so far as it is not purely an individual matter, concerning the instructors or the students, it is again a matter of the starting point.

But there is one matter which must be touched upon—the apparently inevitable tendency to crowd out of the engineering courses all studies which are not definitely specialized. It is a fact to be recognized that many of the students concerned are not likely to take up any post-graduate course of study. And this forces the college into a kind of dilemma. It seems necessary to use most of the time in strictly technical work, in order that the student may be equipped for practical life. But it is also necessary to give the student something of the broader culture, because he will have no other chance for it. The college course is not long enough to fit the boy for the business of life, beginning as far back as it does. The result of the attempt to fit him for some engineering vocation, by depriving him of the wider culture, defeats itself. It neither fits him for the life of business nor for the business of life. And, on the whole, it is more important that he learn how to live, than that he learn how to almost make a living.

The ultimate bearing of this is plain. Engineering education is gradually winning its title to intellectual respect. The engineer enters the fellowship of intelligence by the breadth of his education and the power it develops, not by the income it assures him. There is nothing arbitrary or conventional about this. It is in the nature of the case. As with all kinds of technical training, the narrowing tendency is strong: it gains strength from the constant necessity for specialization; and it alone threatens the respectability of the engineer's standing. I know of nothing this Society could send forth that would be of greater service than a strenuous recommendation that the ineffectual hyper-specialization in the state college be stopped. It might injure the prospects of an individual student here or there, but what of that? If the standard of the educated engineer is raised, the individual student will take care of himself. These colleges cannot turn out engineers, fully equipped. They are not therefore compelled to turn out nondescripts who are so nearly engineers that they are not educated men. It is not even true that the nearer the institution approximates to the complete engineering course, the better for the student taking that course. For that conclusion presupposes that there is nothing to consider except the professional demand. The nature of that demand itself is changing. And one factor in the problem, and one too widely disregarded, is that the students who enter these colleges are not, in the average cases, quite ready for the exclusiveness of professional study. And there is the constant danger that the balance of character be ignored, or destroyed, to the degradation of the profession of engineering in all its branches.

Finally, the so-called agricultural colleges are sending out, each year, more than five hundred men with inclinations toward engineering, if not with an engineering education. This statement, based upon the investigation of Professor Aldrich, ignores entirely the large number of graduates who have simply the degree of Bachelor of Science. The total is constantly increasing. In general, these men have had an excellent elementary training, nothing more. In general, also, this elementary professional course is final for them. What further instruction they are to get must come, save in exceptional cases, from the demands of the work they find to do. And the conclusion is inevitable. These colleges are not likely, for the present, to supply the prophetic engineers. For technology has its prophetic spirits, and their names are household words. Nor are these institutions to supply the mere hewers of wood and drawers of water. For between the highest function and the lowest is a wide range of opportunity. And there the graduate of the state college finds his work. So, in point of fact, it is; so, in the nature of things, it must be. But the conditions are not necessarily final; they are, rather, germinal. And they indicate a potent development of the engineering courses, of the colleges themselves, and of the whole educational system.

Discussion.

Professor Aldrich sent the following discussion, entitled "Some Statistics in Relation to Engineering Education in Federally-Endowed Institutions."

The Federally-endowed institutions are the so-called land grant colleges and the state universities that have been developed from them. They are the beneficiaries of the Federal grants of 1862 and 1890, known respectively as the Land Grant Bill and the Morrill Act. By the first Congressional enactment, each state received a definite grant of 30,000 acres of public lands for each senator and representative in Congress. By the second national endowment the states received equal amounts annually, irrespective of population or the probability of state development; and from the first installment of $15,000, June 30, 1890, the amount is increased by $1,000 each year for ten years, thence to be maintained at $25,000 annually.

These endowments from the proceeds of the sale of public lands have been made to each of "the several states and territories which may provide colleges for the benefit of agriculture and the mechanic arts." By the act of 1862, such branches of learning as are related to agriculture and the mechanic arts were provided for, without excluding other scientific and classical studies, and including military tactics. By the act of 1890, "agriculture, the mechanic arts, the English language, and the various branches of mathematical, physical, natural, and economic science," were specifically provided for; but the classical and the military instruction provided for by the former act are excluded by the latter.

While few engineering courses have been developed and maintained by the first endowment, the second recognized and made possible a development of some degree of engineering education in all the land grant institutions. The second endowment has likewise stimulated private benefactions for the promotion of engineering education, and it came at a time when urgently needed to assist in establishing new and rapidly growing engineering courses, and to aid in providing additional staff and material equipment for them. Up to the present, however, it has not been possible to obtain full information as to the direct benefits that have accrued from the Federal endowments in their relation to engineering education in these state institutions. It is doubtful whether a clearly defined line could be drawn between the benefits of Federal endowments on the one hand, and those made by the individual states and by private benefactors, on the other. The following statistical memoranda may serve, however, to show in what direction engineering education is moving in these institutions.

I. Names of the Federally-Endowed Institutions.

While the official designation of the so-called agricultural colleges was "colleges for the benefit of agriculture and the mechanic arts," it is only in the case of New Jersey, in relation to the Rutgers Scientific School, that this title still adheres. Acts of state legislatures, private benefactions, and other causes have operated to change the names of these institutions directly or to affiliate them with other state institutions, as follows:

Agricultural and Mechanical Colleges,	2
Colleges of Agriculture and the Mechanic Arts,	8
Agricultural Colleges.	13
Polytechnic Institutes (Alabama and Virginia),	2
State Colleges,	4
State Universities (evolved from the original land grant colleges or the state institutions with which such were affiliated).	16
Specially-designated land grant institutions, Clemson Agricultural College, South Carolina. Purdue University, Indiana. Cornell University, New York.	3
Total number of Federally-endowed institutions.	48

In the case of Massachusetts, the agricultural education is given, pursuant to these grants, in the Massachusetts Agricultural College, at Amherst, and the engineering education (under the Congressional caption "mechanic arts") is given in the Massachusetts Institute of Technology, at Boston.

It may be interesting to note the significance of the tendencies in some of the states to meet, or, it may be, to anticipate the movement in engineering education, by designating their land grant institutions as "Polytechnic Institutes."

II. Organization for Engineering Education.

As far as it has been possible to ascertain from special circulars, education in engineering and the mechanic arts in the Federally-endowed institutions is organized as follows:

	Institutions.
Into Departments of Engineering,	26
Into Schools of Engineering,	15
Into Colleges of Engineering,	10
Not organized in any special manner,	9

In some institutions the departments of special branches, as well as the schools of selective branches of engineering, are organized into a College of Engineering, and often under their respective titles. This accounts for the overlapping of the numbers in the above list; some are necessarily counted twice.

III. Attendance on Engineering and Mechanic Arts Courses.

Reported enrolment of fall term, 1896–97.

Number of institutions reported as follows:

	Institutions.
Having attendance in mechanic arts courses alone,	5
Having attendance in engineering courses alone,	11
Having attendance in both engineering and mechanic arts courses,	26
Not reporting any attendance in either engineering or mechanic arts,	6

Attendance on specific engineering courses reported as follows:

	Students.
Civil engineering,	1,516
Mining engineering,	405

Mechanical engineering,	2,505
Electrical engineering,	1,404
Unclassified branches of engineering,	586
Total reported,	6,416

Since many of the students in the above engineering courses take the mechanic arts instruction wholly or in part, the following report of attendance in this course must include some of the above:

	Students.
Attendance in mechanic arts courses,	2,802
Total reported enrolment, fall term, 1896–97, in 47 of the 48 Federally-endowed institutions,	21,794
Proportion of students taking engineering courses,	30 per cent.

IV. DEGREES CONFERRED IN ENGINEERING COURSES IN FEDERALLY-ENDOWED INSTITUTIONS.

Undergraduate.		Postgraduate.	
In Scientific Courses.			
	Institutions.		Institutions
B. S.	39	M. S.	18
M. S.	9	Sc. D.	2
In Engineering Courses.			
B. E.	2		
B. C. E.	8	M. C. E.	1
B. M. E.	7	M. M. E.	1
B. E. E.	4	M. Archit.	1

B. E. M.	4		
B. S. C. E.	3		
B. S. M. E.	4		
B. S. E. E.	2		
B. S. Mech. Arts	2		
C. E.	14	C. E.	11
M. E.	13	M. E.	12
E. E.	9	E. E.	7
E. M.	4	E. M.	3
Chem. Engr.	2		

Degrees not announced in catalogues of 2 institutions.

No engineering degree given in 12 institutions.

V. Graduates from Engineering Courses, with Degrees, in Federally-Endowed Institutions. 1896.

Civil engineering,	95
Mining engineering,	11
Mechanical engineering,	192
Electrical engineering,	161
Architecture,	22
Unclassified engineering,	29
Total,	510

The above enumeration of graduates is from 21 institutions.

No engineering degrees given in 13 institutions.

No list of graduates given in catalogues of . . . . 2 institutions.

Graduates not classified in catalogues of. . . . . .12 institutions.

Where it was not possible to obtain the list and classification of the graduating class of 1896, that of 1895 was selected, but in only a few instances was this necessary.

Total number of graduates, 1896, ... 2,097.

Proportion of students graduating from engineering courses, 25 per cent. of total number of graduates. Compare this with the previous distribution or the proportion of students taking engineering courses, 30 per cent. of total number in attendance.

More complete records, at the present moment, might alter a few of these figures; but they are sufficiently accurate and complete to show in what direction these federally-endowed institutions are moving.

PROFESSOR MEES said that there was one point that it seemed worth while to bring out, namely, the necessity and the justice of individual adaptation on the part of the school to the work before it. That, he thought, is a matter that engineers, as a rule, have overlooked. It seems to be the ambition of every engineering school to do as much as any other school is doing, at any rate on paper. If it were thoroughly understood that the first duty of the school is to fill its place, to do the work that is before it, and to do that well, then the school that does this would stand as high as any other.

PROFESSOR BULL agreed fully with Professor Mees, that the first duty of the school is to fill its place. The question is simply, how can it fill its place? One way of doing that is to bring the common schools and the high schools to a higher level. He thought that quite as important as to try to get as many students as possible.

Professor Mees said he did not think that that could be more strongly emphasized than it was by the author of the paper.

GRADUATION THESES: THEIR PREPARATION, FORM, AND PRESERVATION.

BY IRA O. BAKER.

Professor of Civil Engineering, University of Illinois, Champaign, Ill.

The Purpose.

The sole purpose of the graduating thesis should be to test the student's ability for independent work. In nearly all of his collegiate studies he has been working under direction: the exact pages for the next recitation have been assigned, and the quiz has been held; the data for the problems have been given and the results have been checked by the instructor; the experiments have been planned and the apparatus set up ready for the student. Everywhere he has leaned upon the instructor; only to a limited extent has the instruction cultivated self-reliance and independence. The object of his work has been to acquire information.

The thesis should afford the student an opportunity to apply what he has learned and to test his ability for independent work. In selecting the subject of the thesis, in planning the method of work, in devising apparatus, in determining the conditions to be fulfilled, in checking the data, in formulating the results, the student should take the lead, the instructor giving advice or help sparingly, and then only when the capacity of the student or the time available absolutely demands it. In short, the thesis should throw the student upon his own resources, as in practice, except that in this case the mistakes which might otherwise cost money or life will be pointed out by the instructor.

The Subject.

The ideal topic for a thesis is some subject requiring original research, some subject a thorough investigation of which will push outward the boundary of human knowledge. The student will work with more enthusiasm, with all his powers, if he has a reasonable hope of adding to the sum total of the world's knowledge. However, of the numerous questions in engineering still remaining unanswered, many are not available for thesis subjects. Some are too complicated for the capacity of the student, some never can be solved by any laboratory equipment, some require more time than the student has at his command. On the other hand, not all possible subjects are expedient. Many experimental subjects require multitudinous repetitions of a single simple process, upon which it is unwise for the student to spend the necessary time. For example, it would be a problem in original research to determine the strength of a certain cement with varying portions of sand. To determine this with a creditable degree of accuracy would require the making and breaking of a great number of briquettes, requiring a large amount of time, from which the student would get little or no benefit. To repeat, the object of the thesis is to test the student's ability in overcoming difficulties, in discovering causes, in interpreting results, and not to enable him to attain dexterity in some simple manual or mental operation.

Another class of thesis subjects, only a little, if at all, inferior to original research, is found in design. If the design is that of a new machine to produce some little device, or to perform some simple operation, the topic is to all intents and purposes a problem in original research and is therefore ideal. Again, a report upon a system of water works for some small town at present without such a system, worked up with as much detail as if it were to be submitted to the city council, is entirely satisfactory. Such a subject as the design of a sewerage system for some small town, with an estimate of cost, etc., or a report upon a method of sewage disposal for some particular place, is most excellent.

Frequently the employment of the student during a summer vacation, particularly that between his junior and senior years, affords excellent material for a thesis. The student could describe the method of prosecuting the work and secure the data necessary to determine the various items of cost, keeping a private labor and material account if necessary. Or sometimes a student, by absenting himself from his regular duties for a week or ten days, can visit some work in progress and secure material for a suitable thesis. However, with such subjects it is not sufficient to present merely a description of the work; there should be an investigation of the cost of the various parts, the efficiencies of different methods, etc.

It is not desirable that the thesis should consist of a design closely similar to one worked out previously in the class-room. Nor is there much value in a student's nominally designing a structure to fill the same conditions as one recently designed by a master. The student may compute the stresses in the truss and design the details substantially as well as the master hand, and think that he has made an equally good design; but the structure as built may give no evidence of the fundamental conditions leading to its construction. The computation of the stresses and the working out of the details are the smallest and least important part of the design. The student should determine whether a metal bridge or a masonry arch is required, whether the metal bridge shall be a plate girder or a truss, a fixed or a swing span. It is often difficult for the beginner to determine the controlling factors, and in his thesis work the student should determine these for himself.

The repetition of some experimental investigation is unsuitable for a thesis, in that the student is nearly certain to follow the footsteps of his predecessor, and hence lose the stimulating, invigorating effect of original work.

It is scarcely necessary to say that a thesis which purposes to be only a review of some structure is hardly worthy of consideration. It lacks all the elements of independent original research. Colleges should make more than mere copiers; they should teach how to solve new problems in new ways, and to apply old conclusions in new conditions.

A mathematical or historical investigation of some topic related to engineering makes a good subject for a thesis, the only objection being that it is not connected closely enough with the probable every-day practice of the prospective engineer.

Finally, after all has been said about the ideal subject, the instructor and the student may well be thankful when they have settled upon a subject that the head of the department will approve; and the latter will be reluctant to approve a considerable proportion of the thesis subjects that he finally accepts. In other words, the selection of a suitable thesis subject is no easy matter. Even after it has been approved and considerable time has been spent upon it, not infrequently the subject must be changed.

The Preparation.

Institutions differ greatly in the amount of time allowed for the preparation of the thesis. In some cases, more particularly in natural science, the thesis is the report upon an investigation carried on as a regular study during one, two, or three terms. In other cases, the regular work of the student is lessened or suspended altogether for a certain length of time to permit the student to prepare his thesis. In still other cases the student is expected to prepare his thesis in fractions of time during his senior year. The writer regrets that he is not able to present more definite information as to the practice of institutions in this particular. The catalogues of most institutions give practically no information on this subject. However, the writer is of the opinion that in the great majority of engineering theses the work is of necessity done in fractions of time during the latter part of the senior year.

Before the student begins actual work upon his thesis, he should submit a tentative outline of the proposed investigation. At regular intervals, perhaps once a week, he should submit a written report of progress. The chief purpose of the report of progress is to keep the student at work, but it is also very important as giving information as to the results of the investigation. From an examination of the reports, the instructor can determine when a personal conference is necessary. It is wise to date and file these reports for possible evidence in case the student is dilatory in completing his thesis.

A date should be fixed upon which the supposedly complete thesis should be submitted for the instructor's criticism. Much care should be given by the instructor to the literary form of the thesis. A man may be a really good engineer and yet write indifferent English ; but no one should be allowed to rank as a college graduate who can not write his mother tongue clearly and correctly. An engineering thesis should not be a mere literary essay ; but, on the other hand, it should not violate the fundamental principles of good literary workmanship. It is not sufficient for the engineering professor to say that the student should have learned to write before beginning to study engineering. The writer admits that frequently the student's English is inexcusably, disgracefully bad, and believes that such should not be allowed to secure the college diploma. But from the very nature of the case, even the brightest and best students need friendly criticism and suggestion in the literary work of the thesis. The student may have had thorough training in the department of English in writing paragraphs, essays, biographical sketches, or descriptions of baseball games, and still need suggestions as to the general construction of a thesis. Some students will need criticism only as to the general arrangement of the subject matter, others will require suggestions also as to sentence construction, while a few will need help also in the selection of the proper words to express the thought clearly. It is not necessary to consider the last two further; but the instructor should give careful attention to see that the thesis is arranged in logical form, that the description of apparatus is sufficiently complete and not prolix, that all the essential data are recorded, that the conclusions are justified and stated clearly. As far as possible the data should be tabulated. Graphical representations should be inserted whenever required.

The thesis should be rewritten, more than once if necessary, until it meets the unqualified approval of the instructor.

The Form.

The mechanical form is worthy of attention. Each institution should prescribe a certain size or sizes of paper upon which the thesis is to be presented. If at all possible, all theses should be upon the same size of paper. This is not as difficult nor as objectionable as some will at first think. Large drawings can be reduced by photography if necessary. A very satisfactory size of paper is 8 inches by 10 inches, not including 1½ inches on one side for binding. Of course proper margins should be left.

Some institutions require that the matter shall be in the student's own handwriting, while others require that it shall be in typewriting. There are good reasons for each of these views, but the writer prefers the middle ground of requiring the text to be in typewriting, and all tables and formulas, including letters in the text referring to the formulas, to be in the student's own handwriting.

The thesis should have a title page neatly printed by hand or from movable type. There should also be a table of contents.

The thesis should be presented in a manilla envelope, unbound or in temporary binding; and the institution should subsequently bind all theses separately and catalogue them in the college library.

After the thesis is supposedly in its final form, the student should "read it by copy," carefully comparing all data with a well-authenticated copy. Afterwards the instructor should carefully read the entire thesis.

In conclusion, the writer desires to commend most highly the practice of some institutions of requiring the student to present his thesis before instructors and students. The writer is aware of some of the difficulties of this practice, but he is of the opinion that the advantages greatly outweigh the disadvantages. The fact that the student is to defend his thesis before his fellow students and his instructors, and perhaps also before alumni and other engineers, will greatly stimulate his interest and energy. However, as the writer has not yet been able to have the theses of his students thus presented, perhaps nothing further should be said on this phase of the subject.

In conclusion, the writer desires to re-affirm his belief in the value of the thesis both as a means of instruction and as a test of the student's ability to do independent work. The value to the student is exceeded only by the tax on the instructor.

Discussion.

Professor Kidwell said he wished to add a word as to the final disposition of the theses, a point which was not touched upon in the paper. A plan that he had found very convenient was to make it a rule that in binding theses all plates should be separate; that they should be made on very tough bond paper, either of a standard size, or of some multiple of that size, and folded, and that the binding should be provided with a large pocket so that these could be slipped into it and kept entirely separate. The reason for this was that it had been found from the nature of their work that occasions arose when it would be very beneficial to have copies of these drawings, and by this method the originals could be pulled out quickly, blue-printed in any number, and then restored to their place. He did not know that this method would be of value to any one else, but he had found it very convenient for his purposes.

Professor Caldwell said he was just putting into effect at the Ohio State University a scheme for filing theses, that he believed would prove very useful. He found it very difficult to get the name of each thesis printed on the back, because the theses were generally quite thin when bound. He filed the theses in a box as cards are filed in card catalogues. The theses fit somewhat loosely in the box, which has an inclined back, so that the theses can be run over and any particular thesis picked out without disturbing the others.

Professor Kidwell said he had had similar trouble, but that the addition of the pocket increased the thickness to such an extent that there was no further difficulty in stamping the title on the back.

Professor Mees wished to ask a question; he did not quite know whether it was pertinent or impertinent. He wished to know the experience or the practice of any who might choose to give it, as to what the thesis means. That is, what is done with it? What part does the thesis play in determining the rank of the student or in giving him his degree? In other words, what weight is attached to the thesis in the estimate of the work?

Professor Carpenter said he thought that the practice varied in different colleges. He knew that it varied in the different departments at Cornell University. For instance, certain literary departments had lately abolished the thesis as a requirement of graduation, while in the technical departments the thesis was considered of very great value and was required for graduation. In Sibley College, there is allowed for its preparation a definite number of hours in the course, equivalent to about two thirds of one full term's work; the student is marked on his thesis, as on recitations, and a certain standing is required for acceptance. The general principles that are enforced are practically those laid down by Professor Baker. In Sibley College the thesis counts for twelve University hours for one term, which is about two thirds of a term's work.

Professor Johnson asked if the student's other work is reduced by that amount.

Professor Carpenter replied in the affirmative, and added that if the thesis work is not specifically passed the student does not graduate. But the students usually put in more than the required twelve hours; some of them put in a great deal more. Some of them produce very valuable theses, while of course a great many are merely up to the passing mark, and sometimes they are so poor that they must be rejected. The usual work for a term in Sibley College is eighteen University hours per week, in which three hours in shop or drawing-room, two and one half hours in laboratory, or one in recitation, counts as one hour. The last term of the senior year requires twelve hours for thesis and six hours for other work.

Professor Bull stated that the practice at the University of Wisconsin agrees entirely with that at Sibley College. He did not remember whether exactly twelve hours are allowed for the thesis, but it is something like that. The class work is diminished by that amount, and the students are marked on thesis work as on other work. If a student should fail in a study he would, of course, not be graduated; nor would he be graduated if he should not hand in a satisfactory thesis.

Professor Flather said that at Purdue University the practice is essentially the same, although they allow sixteen hours for the thesis, and diminish the other work to the same extent.

President Eddy inquired what fraction of the term's work the sixteen hours represent.

Professor Flather replied that it is less than one half. In their method of counting, the sixteen hours are actual hours; and the work that he referred to is in the drawing-room, in which each hour counts for an hour. Therefore, the sixteen hours might be less than the time represented by the same number of periods in other colleges. The sixteen hours represents the actual time assigned to thesis work. The men usually devote a great deal more time to it, but they are required to give that amount.

In his thesis work, the student is thrown largely on his own resources. At first, the work is laid out and suggestions are made as to how to proceed, but after that he is responsible for the satisfactory completion of the work. The thesis abstract or draft must be submitted at a specified time, about three weeks before Commencement. If this draft, the preliminary part of his thesis, is not satisfactory, it is returned to the student, and he must revise his work and return it performed in a better, more thorough manner. The professor in charge is consulted more or less from time to time, but he is regarded as an adviser rather than as a director of the work.

Professor Wernicke stated as the practice in the State College of Kentucky that in the last term of the senior year grades for the studies besides the thesis are averaged with the results of examinations, and on the other hand the thesis is also allowed a certain credit; and these two credits, thesis and term credits, are averaged to form the final grade for the last term of the senior year.

Professor Mees said he was very glad to obtain this information, and in return would state that for the last year or two the method at the Rose Polytechnic Institute had been to bunch this work, giving the students five weeks in which to take up the investigation and carry it through. The grading of the thesis is done by an examining committee. The thesis is read either in full or in abstract before the examining committee, consisting of two or three members of the faculty, together with at least three men from the outside, representing various bodies, professional engineers or men who are engaged in practice, and the committee then weighs the theses, and their grade is valued as twenty per cent. of the second term. The thesis is weighted to that amount in the general average.

Professor Carpenter said that from his own experience with the production of theses, he would say that better results are obtained when the same number of hours can be spread over a longer period of time than when they are crowded into a very short period. The speaker had requested his colleagues to allow a certain small amount of time from each of the three terms rather than the same gross amount from one term. In Cornell University, twelve university hours means three hundred actual hours of work, and he thought that, beginning with next year, there would be allowed for thesis work fifty hours in the first term, seventy-five in the second, and the remainder in the third term. He thought such a distribution would yield much better results than the present allowance of three hundred actual hours in a single term.

MEMORIAL NOTICE OF PROFESSOR DE VOLSON WOOD.

The Society for the Promotion of Engineering Education, at its formal organization during the International Engineering Congress of 1893, exercised a discretion no less wise than spontaneous in choosing for its first President, Professor De Volson Wood. He had then been a teacher of engineering, first in the University of Michigan and then in the Stevens Institute of Technology, for nearly forty years; and he had almost attained his fiftieth year of continuous work as an educator and as a writer in the fields of engineering when his indefatigable labors were closed by death on June 27, 1897.

Professor Wood was a great teacher. He inspired his students by his clear and logical thinking, by his manly character, and by his invigorating presence, and the remembrance of his noble manhood and tireless energy remained with those students, a stimulus to similar manhood and energy. He wrought himself so effectively into the characters of the hundreds of young men who came under his instruction that his influence grew to be far-reaching. Few, if any, have done so much as he to promote engineering science in America, and no one has done more to maintain an elevated standard for the engineering profession.

His students, who always revered him as an instructor and as a friend, will ever cherish his memory; his fellow teachers will miss his cheerful and gracious presence, and will remember with gratitude the kindly and helpful advice he was ever ready to give; and this Society, while realizing keenly the loss of a wise counselor and an active contributor to its Proceedings, will hold in grateful remembrance the splendid example he set of the upright man whose years are filled with usefulness.

The following brief sketch of Professor Wood's life, prepared by one of his pupils and published originally in *Science*, is here reprinted as a permanent record of his life work.

Professor De Volson Wood was a man of unusual attainments and was for nearly half a century identified with the promotion of that systematic technological education which has come to play so important a rôle in the civilization of the present day. He was born in 1832, and passed the years of his youth on the farm of his father near Smyrna, N. Y. He early displayed the capacities of a successful student and teacher of mathematics. The neighbors used to say that "the stones on Mr. Wood's farm are covered with figures which his son De Volson used in the solution of problems." He began teaching school at the age of seventeen. After some preliminary studies at a private academy and at the Cazenovia Seminary, he went to the New York State Normal College, at Albany, in 1852, and was graduated from that institution at the end of the following year. During 1853–4 he was principal of the public school of Nopanoch, N. Y.; and during 1854–5 he served the New York State Normal College as Assistant Professor of Mathematics. He then went to the Rensselaer Polytechnic

Institute at Troy, N. Y., where, after two years' work as student and instructor, he was graduated with the degree of Civil Engineer. Immediately thereafter he became connected with the University of Michigan, in which he served as Assistant Professor of Civil Engineering from 1857 to 1859, as Professor of Physics and Engineering from 1859 to 1860 and as Professor of Civil Engineering from 1860 to 1872. At the end of the latter academic year he resigned his professorship in the University of Michigan to accept the professorship of Mathematics and Mechanics in the Stevens Institute of Technology, which had been founded the same year. He remained with this institution until his death, holding the professorship of Mathematics and Mechanics until 1885, and from that year on the professorship of Mechanical Engineering.

It is an interesting circumstance, which in some measure undoubtedly determined Professor Wood's career, that he went to the University of Michigan shortly after President Henry Philip Tappan began his remarkable educational work in that institution. Tappan, considering the time in question, was a man of very broad and liberal views concerning educational affairs, and was one of the first to introduce in this country the German ideas of the functions and administration of a university. He was also one of the first of our educators to recognize the value of technological studies, and under his guidance there was established in the University of Michigan, as early as 1855, a four years' course in engineering, to the conduct of which Professor Wood was called two years later. Two other brilliant men of the same institution, into whose society Professor Wood was thrown at this time, were the distinguished astronomers Francis Brünnow and James C. Watson. A more stimulating intellectual environment than that furnished by these three men could not have been found in this country at that time.

From the time he went to the University of Michigan, in 1857, to the end of the present academic year, Professor Wood was actively engaged in the work of instruction, rarely missing a day from his class-room in forty-one years. During the earlier part, especially, of this long interval, before the differentiation of studies now common had been obtained, he gave instruction in a variety of subjects, embracing, in fact, nearly all those of the mathematico-physical sciences in the engineering curriculum. He was thus brought into intimate contact, and, in many cases, into prolonged association, with a large body of students, who have borne abundant testimony to the exceptional value of his instruction and influence by the range and efficiency of the work they have accomplished. The peculiar merit of his teaching lay in his capacity to make men think for themselves, laboriously and enthusiastically. He was generally able to get students to devote willingly to his subjects from three to five times as much labor as they would give to the subjects of other instructors. As he was a man of untiring industry, full of suggestions and inquiries, and animated always by a robust and transparent love of the truth, only the dullest students could fail to make creditable progress under his guidance. This genius for industry and this capacity for self-help are the elements of character he succeeded in planting firmly in the long list of engineers who had the good fortune to come under his instruction.

Professor Wood was a frequent contributor to scientific periodicals, particularly those devoted to mathematics and engineering. He was also the author of several text-books widely used in schools of engineering. In this work, as in teaching, his activity was indefatigable to the last, a revised and enlarged edition of his important work on water motors having been brought out shortly before his death.

In appearance Professor Wood was a striking figure. His large, erect frame and his energetic manner at once commanded attention and respect. Socially he was a most genial and kindly man, full of patience and encouragement, especially for young men. He was of a somewhat retiring and domestic disposition, however, and mingled less with men of the world than might have been expected. Though honored by election to office in the scientific societies to which he belonged, he never sought personal advancement. He was content with his chosen work in the class-room, and the remarkable success he attained in that work amply justifies the singular fidelity with which he devoted his life to it.

J. B. Johnson,
R. S. Woodward,
William Kent,
Committee.

Library
N. C. State College

INDEX.

PAGE.
Address of President H. T. Eddy, On Engineering Education, ... 11
Agricultural College, in its Relation to Engineering Education, C. S. Murkland, ... 295
Aid to Students in Specific Research, ... 47
Aldrich, W. S., Discussion, ... 304
Allen, C. F., Discussions, 113, 126, 158, 224, 233, 237, 241, 260, 261, ... 284, 288
Amendment to Constitution, ... 2
American Technical Schools, Prof. A. Riedler on, ... 47
American Testing Laboratories, Prof. Martens on, ... 51
Anilin Dyes, Production of, ... 178
Apprentices and Technical Students, ... 106, 114, 115
Apprenticeship and Trade Schools, ... 268
Artisans, Manual Training for, ... 264
Attendance on Engineering and Mechanic Arts, Courses in Federally-endowed Institutions, ... 307

Baker, I. O., Graduation Theses, ... 312
Beet-Sugar Industry, Development of, ... 169
Bleaching by Chlorin, ... 164
Boardman Manual Training High School, Mathematics Taught in, . . 275
" " " " " Elementary Mechanics Taught in, ... 276
Bull, Storm, Discussions, ... 156, 195, 208, 209, 310, 322
Bunte, H., Influence of Scientific Research Upon the Development of Chemical Technology, ... 161

Calculus for Engineering Students, F. W. McNair, ... 139
Calculus, Graphical Illustrations in, ... 110
Caldwell, F. C., Discussion, ... 103, 320
Carpenter, R. C., Engineering Laboratory Courses, ... 26
" Discussions, ... 133, 292, 321, 322, 324
Chemical Engineering, J. M. Ordway, ... 187
Chemical Technology, Influence of Scientific Research Upon the Develoрent of, ... 161
Chicago Manual Training School, Methods in, ... 292
Coal Tar, Utilization of, ... 178
Columbia University, Elective Studies in, ... 124
Committees, Lists of, ... v

Committee, Nominating, Appointment, ... 4
" " Report, ... 6
" on Memorial of Professor Wood, ... 1
" on Entrance Requirements, ... v, 5
Constant, F. H., Discussion, ... 228
Constitution, ... xxi
" Amendments to, ... 2
Cooley, M. E., the Extent to which Metallurgy should be taught in Mechanical Engineering Courses, ... 262
Council, List of Members of, ... vi
" Rules Governing the, ... xxii
Councils, Members of Previous, ... xx
Course in French and German for Engineers, A. N. Van Daell, ... 247
Course of Study in Electrical Engineering, R. B. Owens, ... 40
Creighton, W. H. P., Methods of Teaching, ... 104
Culture Studies, ... 13, 134, 136
Degrees Conferred in Federally-endowed Institutions, ... 300, 308
Degree of Electrical Engineer, ... 46
Design, Methods of Teaching Dynamo, ... 42
" The Teaching of Machine, ... 200
Distribution of Members, ... xix
Dyeing, Use of Madder in, ... 164
Dynamics, Symbols for, ... 77
Dynamo Design, Methods of Teaching, ... 42

Eddy, H. T., Presidential Address, On Engineering Education, ... 11
" " Discussions, 39, 51, 52. 100, 126, 135, 151, 152, 155, 193, ... 197, 224, 225, 229, 288, 322
Education, Definitions, ... 215
Education and Training, ... 215
Efficiency of Technical as Compared with Literary Training, T. C. Mendenhall, ... 211
Elasticity of Materials, Symbols for, ... 77, 84
Elective Studies in the Regular Engineering Courses, H. S. Munroe, . . 117
Elective Studies in Columbia University, ... 124
" " " Massachusetts Institute of Technology, ... 124
" " " University of Michigan, ... 124
Electrical Engineer, Degree of, ... 46
" Engineering, a Course of Study in, ... 40
" " Symbols, ... 55
" Laboratory Methods, ... 44
Electricity, Special Lectures on, ... 45
Elementary Mechanics, Taught in Manual Training High School, . . 276
Engineering Education.
Organization of, in Federally-endowed Institutions, ... 306

Engineering Education.
Presidental Address, H. T. Eddy, ... 11
Statistics in Relation to, in Federally-endowed Institutions, . . 303, 304
The Agricultural College in its Relation to, C. S. Murkland 295
Engineering Laboratory Courses, R. C. Carpenter 26
Entrance Requirements, Committee on, ... v, 5
" " to Engineering Courses, ... 46
Ethical Instruction for Engineers, ... 22
Explosives, Development of Manufacture of, ... 124

Federally-endowed Institutions, Statistics Relating to Engineering Education in, ... 348
Fertilization, Liebig's Theory of, ... 175
Fertilizers, Commercial, ... 177
Flather, J. J., Discussions, ... 207, 259, 263, 322, 323
The Teaching of Machine Design, ... 200
Formulas, ... 109
Framed Structures, Symbols for, ... 84
French and German for Engineers, A Course in, ... 247

Galbraith, John, Discussions, ... 228, 233
" " Symbols for Statics, Dynamics, Strength and Elasticity of Materials, Hydraulics, and Thermodynamics, . . 77
Gas, Development of Illumination by, ... 171
German and French for Engineers, a Course in, ... 247
Graduate Research Work, ... 51
Graduates from Federally-endowed Institutions, ... 309
Graduation Theses: Their Preparation, Form, and Preservation, I. O. Baker, ... 312
Graphical Illustrations in the Calculus, ... 110
Gray, Thomas, Discussions, ... 114, 157
Greek Letters as Symbols, ... 53, 73, 78, 93, 95
Greenhill, A. G., Discussions, ... 90, 135
Gunpowder, Development of Manufacture in France, ... 167

Hospitalier's Notation, ... 59, 61, 91, 102
Hydraulics, Symbols for, ... 77

Illumination by Gas, Development of, ... 171
Influence of Scientific Research Upon the Development of Chemical Technology, H. Bunte, ... 161

Jackson, D. C., Electrical Engineering Symbols, ... 55
Johnson, J. B. Discussions, . 38, 51, 136, 137, 149, 152, 193, 194, 284, 322
" " Symbols for Strength of Materials, Framed Structures, Masonry, and Surveying, ... 84

Kent, Wm., Discussion, ... 73

Kent, Wm., Mechanical Engineering Symbols, ... 67
Kidwell, Edgar, Discussions, 129, 135, 153, 195, 209, 225, 227, 236, 237, ... 320, 321
Knot, Unit of Speed, ... 99

Laboratories, American Testing, Prof. Martens on, ... 51
Laboratory Courses, Engineering, ... 26
Laboratory Instruction, Instituted by Liebig, ... 173
Laboratory Methods, Electrical, ... 44
Lambert, P. A., Discussion, ... 228
Lectures on Electricity, Special, ... 45
Liebig, Laboratory Instruction Instituted by, ... 173
Liebig's Theory of Fertilization, ... 175
Literary and Technical Training, Efficiencies Compared, ... 211

Macfarlane, Prof., Discussion, ... 102
Machine Design, the Teaching of, ... 200
Magruder, W. T., Discussion, ... 198, 209
Manual Training High School, T. W. Mather, ... 272
Manual Training for Artisans, C. M. Woodward, ... 264
Manual Training,
  In Chicago Manual Training School, ... 292
  In Massachusetts Institute of Technology, ... 290
  In Washington University, ... 284
  In Worcester Polytechnic Institute, ... 293
  Russian System of, ... 281, 286, 289, 290
Martens, Prof., on American Testing Laboratories, ... 51
Marx, C. D., At What Point Should Students Engage in Specific Research? 47
Masonry, Symbols for, ... 86
Massachusetts Institute of Technology,
  Elective Studies in, ... 124
  Russian System of Manual Training in, ... 290
  School of Mechanic Arts in, ... 286
Mather, T. W., The Manual Training High School, ... 272
Mechanic Arts, School of, in Massachusetts Institute of Technology, 286
Mass and Weight, ... 74, 81, 90, 97
Mathematics in Engineering Education, ... 15
Mathematics Taught in Boardman Manual Training High School, . . . 275
MacMahon, James, Discussion, ... 197
McNair, F. W., Calculus for Engineering Students, ... 139
Mechanical Engineering Symbols, Wm. Kent, ... 67
Mechanical Engineering Courses, Metallurgy in, ... 262
Mechanic Arts Courses, Attendance on, in Federally-endowed Institutions, ... 307

Mechanics, Elemementary, Taught in Boardman Manual Training High School, ... 276
Mees, C. L., Discussions, ... 225, 237, 310, 311, 321, 323
Members, List of, ... vii
  Distribution of, ... xix
Memorial Notice of Professor De Volson Wood, ... 325
Mendenhall, T. C., Discussion, ... 89
  The Efficiency of Technical as Compared with Literary Training . . 211
Metallurgy, Extent to which it should be taught in Mechanical Engineering Courses, ... 262
Methods of Teaching, W. H. P. Creighton, ... 104
  " " " Dynamo Design, ... 42
  " " " in U. S. Naval Academy, ... 104
Michigan, University of, Elective Studies in, ... 124
Munroe, H. S., Elective Studies in Engineering Courses, ... 117
Murkland, C. S., The Agricultural College in its Relation to Engineering Education, ... 295
  Discussions, ... 224, 226, 239, 245
Nominating Committee, Appointment, ... 4
  " " Report, ... 6
Notation, Hospitalier's, ... 59, 61, 91, 102
  " Rankine's, ... 54, 94

Officers, List of, ... v
  " " " Past, ... xx
Ordway, J. M., Chemical Engineering, ... 187
  Discussions, . . . 134, 154, 193, 196, 207, 208, 209, 242, 263, 286, 290, 294
Ostrander, J. E., Discussion, ... 160
Owens, R. B., A Course of Study in Electrical Engineering, ... 40

Past Officers, List of, ... xx
Presidential Address, H. T. Eddy, ... 11
Proceedings, ... 1

Rankine's Notation, ... 59, 94
  " Use of Stress, ... 82
Report of Secretary, ... 8
  " " Treasurer, ... 9
  " " Committee on Uniformity of Symbols, ... 53
Research, At what Point should Students engage in Specific? 47
  " Scientific, Influence upon the Development of Chemical Technology, ... 161
Research Work by Graduate Students, ... 51
Riedler, A., on American Technical Schools, ... 47
Rules Governing the Council xxii
Russian System of Manual Training, ... 281, 286, 289, 290
  " " in Massachusetts Institute of Technology, ... 290

Sackett, R. L., Discussions, ... 127, 155

Scientific Research, Influence upon the Development of Chemical Technology, ... 161

Secretary, Report of, ... 8

Sibley College, Laboratory Instruction in, ... 26

" " Thesis Work in, ... 321

Sloyd, Origin and Development, ... 291

Soda, Development of Manufacture, ... 164

Special Lectures on Electricity 45

Specific Research, at what Point should Students engage in? 47

Statics, Symbols for 77

Statistics in Relation to Engineering Education in Federally-endowed Institutions, ... 304

Strength of Materials, Symbols for, ... 77, 84

Stress and Strain 74, 82, 89

Subscripts with Symbols, Objections to, ... 73

Surveying, Symbols for, ... 87

Symbols, Electrical Engineering 55

Symbols for Engineering Text-books, Uniformity of, Committee on, . . v

Report of Committee, ... 53

Symbols for Statics, Dynamics, Strength and Elasticity of Materials, Hydraulics, and Thermodynamics, J. Galbraith, ... 77

Symbols for Strength of Materials, Framed Structures, Masonry, and Surveying, J. B. Johnson, ... 84

Symbols, Greek Letters as, ... 53, 73, 78, 93, 95

Symbols, Mechanical Engineering, ... 67

Table of Contents, Volumes V., I., II., III., IV., ... iii

Teaching of Machine Design, J. J. Flather, ... 200

Technical and Literary Training, Efficiencies Compared, ... 211

Technical Schools, American, Prof. A. Riedler on, ... 47

Technical Students and Apprentices, ... 106, 114, 115

Technical Studies, ... 19

Technology, Chemical, Influence of Scientific Research Upon the Development of, ... 161

Testing Laboratories, American, Prof. Martens on, ... 51

Text-books, Report of Committee on Uniformity of Symbols for, . . . 53

Text-books, Use of, ... 146

Thermodynamics, Symbols for, ... 77

Theses, Graduation, Their Preparation, Form, and Preservation, . . . 312

Thomas Process, Development of, ... 183

Trade Schools and Apprenticeships, ... 268

Training and Education, ... 213

Treasurer, Report of, ... 9

Tyler, H. W., Discussions, ... 154, 155, 196, 284

Uniformity of Symbols for Engineering Text-books,
  Committee on, ... v
  Report of Committee 53
Unwin, W. C., Discussion, ... 100
U. S. Naval Academy, Methods of Teaching in, ... 104

Van Daell, A. N., A Course in French and German for Engineers, . . . 247

Waldo, C. A., Discussions, ... 228, 288, 293
Washington University, Manual Training in, ... 284
Weight and Mass, ... 74, 81, 90, 97
Wernicke, P., Discussions, ... 197, 258, 260, 261, 323
Wood, De Volson, Memorial Notice of, ... 325
Woodward, R. S., Discussion, ... 93
Woodward. C. M., Manual Training for Artisans, ... 264
Worcester Polytechnic Institute, Manual Training in, ... 293